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Leveraging AI to uncover the effects of pivotal moments in the LIBOR framework and its evolution on the banking sector

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Abstract

This study aims to investigate the impact of significant events related to the London Interbank Offered Rate (LIBOR) scandal and its transition on the U.S. banking sector. The research utilizes multiple linear regression analysis to assess the relationship between the Dow Jones United States Banks Index and various financial variables, including LIBOR rates, gold prices, and the Volatility Index. The analysis covers data from May 2010 to September 2020, processed using Python. The results indicate that LIBOR rates significantly influence the Dow Jones United States Banks Index, particularly during the periods surrounding the LIBOR scandal and its subsequent discontinuation. The findings highlight LIBOR's critical role in shaping the performance of the banking sector during tumultuous events. Insights from this study provide valuable guidance for financial analysts and policymakers in understanding the dynamics between interest rates and banking sector stability.

Keywords: Dow Jones United States Banks Index, Financial Markets, Fintech LIBOR, Performance, U.S. Banking Sector.

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1. Introduction

An interbank rate refers to the interest rate that banks use to lend to or borrow from each other in the interbank market. The interbank market is where banks and financial institutions make short-term borrowing and lending transactions in order to manage their liquidity needs and to meet regulatory requirements. Interbank rates play a vital role in determining the cost of funds for banks, and they also serve as a benchmark for other interest rates in the financial market. These rates are typically influenced by various factors, including central bank policies, market demand and supply dynamics, and

important economic conditions. Interbank rates are often used as reference rates for setting the interest rates on loans, mortgages, derivatives, and other financial instruments. One of the most well-known interbank rates is LIBOR (London Interbank Offered Rate), which represents the average interest rate at which major banks in London are willing to lend to each other. Other countries and regions may have their own interbank rates, such as EURIBOR (Euro Interbank Offered Rate) in the Eurozone and TIBOR (Tokyo Interbank Offered Rate) in Japan. Interbank rates are crucial indicators of the overall health and liquidity of the banking system. They reflect the confidence and willingness of banks to lend to each other, which, in turn, affects the availability and cost of credit in the broader economy.

1.1. Overview of The London Interbank Offered Rate (LIBOR)

The London Interbank Offered Rate (LIBOR) is a benchmark interest rate that represents the average interest rate at which major banks in London are willing to lend to each other in the international interbank market. LIBOR serves as a reference rate for various financial instruments, including adjustable-rate mortgages, business loans, derivatives, and other contracts. It is calculated and published daily in multiple currencies and various maturities, such as overnight, one month, three months, six months, and one year.

1.2. Historical Significance of LIBOR.

LIBOR has been a widely used benchmark since its introduction in the 1980s. It played a critical role in facilitating global borrowing and lending transactions through providing a common reference point for interest rates across financial markets. Its widespread adoption made it a key determinant of borrowing costs for individuals, businesses, and financial institutions worldwide. Nevertheless, over time, concerns emerged regarding the reliability, transparency, and robustness of LIBOR, which in turn, turned into to calls for its reform and transition to alternative reference rates.

1.3. Need for Transition: The LIBOR Scandal

The need for transitioning away from LIBOR stems from several factors, mainly the manipulation scandal as LIBOR faced significant integrity issues due to manipulation scandals that happened in the late 2000s and early 2010s. Several banks were found to have manipulated LIBOR submissions for their own gain, leading to a loss of confidence in the rate and raising questions about its credibility. How was LIBOR manipulated? Banks submit their estimated borrowing rates to the Intercontinental Exchange (ICE) each day, which are then used to calculate LIBOR. During the scandal, it was revealed that some banks were intentionally submitting inaccurate rates to manipulate LIBOR in their favor. The manipulation occurred in two main ways:

a. Lowballing: Some banks submitted artificially low borrowing rates to create an impression of financial strength or to avoid speculation about their financial health.
b. Profit-driven manipulation: Traders at certain banks colluded with each other and submitted false rates to benefit their trading positions tied to LIBOR.

The LIBOR scandal unfolded over a series of events that had far-reaching consequences for the global financial system. It all began in 2007 when Barclays raised concerns with U.S. regulators, signalling that some banks were reporting artificially low interbank rates. The situation escalated dramatically in September 2008 when LIBOR rates spiked following the collapse of Lehman Brothers during the height of the global financial crisis. The gravity of the situation became even more apparent in 2010 when the UK's Financial Services Authority (FSA) initiated an investigation into Barclays as part of a broader global probe into allegations of interest rate manipulation. In August 2011, Charles Schwab Corp. filed lawsuits against 11 major banks, alleging a conspiracy to manipulate LIBOR.

By June 2012 (Event 1), Barclays found itself at the center of the storm and agreed to pay a hefty $450 million settlement to U.S. and British regulators over rate rigging. The scandal led to the resignation of top Barclays executives, including Chief Executive Bob Diamond and Chairman Marcus Agius, in the following month. In August 2012, an investigation by New York and Connecticut authorities prompted subpoenas to be issued to several major banks, including the Royal Bank of Scotland, HSBC Holdings, JPMorgan, Deutsche Bank, Barclays, UBS, and Citigroup. These subpoenas sought communication records related to potential collusion in alleged rate manipulation. September 2012 saw the UK's FSA propose a 10-point plan aimed at reforming the LIBOR framework, although the benchmark interest rate itself remained intact. In November 2012, Deutsche Bank faced questions from German lawmakers about its involvement in manipulating global benchmark rates. On the same day, Barclays announced disciplinary action by firing five employees as part of its investigations into LIBOR rigging.

As the year drew to a close in December 2012, UBS faced a substantial penalty of $1.5 billion to settle charges of rigging LIBOR. This marked a significant turning point as U.S. prosecutors also criminally charged two former UBS traders, Tom Hayes and Roger Darin, making them the first individuals to face such accusations in connection with the manipulation. Additionally, UBS's Japanese subsidiary pleaded guilty to a U.S. criminal count of fraud in relation to benchmark rate manipulation. In February 2013, the Royal Bank of Scotland (RBS) faced the consequences of its role in the global rate-rigging scandal and was fined $612 million. The manipulation by RBS extended from at least 2006 until late 2010, a period that extended beyond the bank's bailout. Responding to these developments, John Hourican, head of RBS's investment bank, announced his departure, effective at the end of April 2013.

These events serve as a stark reminder of the far-reaching consequences and intricate nature of the LIBOR scandal and its subsequent impact on the financial landscape.

By 2017-07-27 (Event 2): the Financial Conduct Authority (FCA) made a groundbreaking announcement - the official discontinuation of the London Interbank Offered Rate (LIBOR) by the end of 2021. This declaration marked a watershed

moment in the financial world, necessitating a shift to alternative benchmark rates. Event 2 highlights the adaptability of the industry and the broader context of transitioning from legacy financial benchmarks. The significance of this declaration was acknowledged by key figures such as the head of the FCA, Andrew Bailey, who played a pivotal role in the declaration to phase out LIBOR. He emphasized the imperative for a more reliable benchmark rate, stating, "The discontinuation of LIBOR is a momentous step, reflecting the necessity for a benchmark that aligns with market realities." Add to that, Jerome Powell, Chairman of the U.S. Federal Reserve, who underscored the importance of preparing for the discontinuation of LIBOR in the United States, saying, "The discontinuation of LIBOR is an event of significant magnitude that necessitates careful planning and execution across various sectors."

2. Literature Review

Our research focuses on assessing the effects of key events associated with the LIBOR transition and scandal on the banking sector. We delve into the intricate dynamics of how these events have influenced the performance of the banking industry, shedding light on their profound impact. While some variables have received considerable attention in the literature, others remain relatively unexplored. By analyzing and interpreting relevant events, we aim to gain insights into the nuanced relationship between these variables and their impact on the U.S. banking sector. In the realm of literature exploring potential manipulations within the financial industry, a pivotal inquiry emerged: were manipulative practices indeed occurring, and if so, what were their underlying mechanisms? [1] ignited suspicions of deliberate underreporting of rates by panel banks, setting off a wave of academic investigations aimed at substantiating claims of rate-fixing. Notable contributions to this discourse include Gyntelberg and Wooldridge [2];Taylor and Williams [3];Taylor and Williams [4];Snider and Youle [5];Abrantes-Metz, et al. [6];Abrantes-Metz, et al. [7];Monticini and Thornton [8] and Gandhi, et al. [9]. The collective findings of these scholars predominantly support the existence of manipulation. Residual doubts dissipated between 2012 and 2015 when financial giants such as Barclays, Deutsche Bank, and UBS reached settlements in the US, UK, and Euro Area. Berkovitch, et al. [10] Our research also closely aligns with the study of Berkovitch, et al. [10], which used regression to examine the impact of LIBOR and financial constraints on stock returns during LSP events. These variables and control measures are essential in assessing the relationship between financial market events, such as the LIBOR scandal or discontinuation, and stock price movements, thereby contributing to the broader body of research in this field [11]. The dynamics of gold prices have exhibited a profound interplay with significant economic events, a facet pertinent to our research goals. Notably, in the wake of the 2008 financial crisis and the subsequent Eurozone debt crisis, the value of gold surged from $1,000 per ounce in 2009 to $1,895 by September 2011 [11]. Additionally, historical occurrences such as the United States' departure from the gold standard in 1976 precipitated a substantial ascent in gold prices, soaring from $42 to $120 per ounce [11]. These fluctuations underscore the potential of gold prices to serve as vital indicators, reflecting economic conditions. Heightened gold prices often connote looming inflation or economic fragility, with investors perceiving gold as a safeguard during tumultuous periods. Within this context, it is imperative to explore the multifaceted channels through which gold prices and interest rates may interconnect [12-14]. This research delves into the characteristics of daily stock returns and their influence on event study methodologies employed to evaluate the impact of specific events on share prices. In comparison to event studies conducted with other types of data, this research shows that daily data typically pose fewer challenges. Even when distinctive daily data traits are disregarded, standard procedures often yield satisfactory results.

Fabrizi, et al. [15]: This study investigates whether the presence of shared incentives and opportunities to engage in fraudulent activities trigger reputational contagion, affecting not only culpable firms but also nonculpable ones. Utilizing a dataset comprising 30 banks implicated in the manipulation of the London Interbank Offered Rate (LIBOR) and a control group of 30 banks, this research revealed significant damage to the reputations of banks following the revelation of their involvement in the scandal.

Karafiath [16]: This paper introduces a novel approach that combines event studies with regression models using dummy variables. This technique streamlines the process of acquiring cumulative prediction errors and associated test statistics. By incorporating a vector of (0,1) dummy variables into the market model, tasks traditionally accomplished in two separate steps can now be achieved in a single multiple regression analysis. One significant advantage of this approach is its ability to efficiently generate prediction errors and accurate test statistics using standard regression software, making it a valuable tool for event studies within a regression framework.

Overall, this study examines the impact of key financial and economic variables on the performance of the U.S. banking sector. By investigating this relationship, valuable insights can be gained to support informed decision-making by investors, bankers, and policymakers. While some studies have examined the influence of LIBOR rates or LIBOR-CDS spreads and specific events using dummy variables, there is a gap in the literature regarding the specific impact of variables such as gold prices and the behavior of the CBOE VIX Index. Further research in these areas would contribute to a more comprehensive understanding of the effects of the LIBOR scandal and transition factors on the performance of the U.S. banking sector.

In the financial Development and Banking Stability [17] highlight the importance of financial development in ensuring economic prosperity, particularly for East Asia and Pacific countries. Their research shows that economic growth relies on financial stability, a key focus for the current study as it deals with LIBOR transitions that have implications for financial stability and bank performance in the U.S.

In the economic growth and financial markets, the influence of the above factors on financial markets has been thoroughly studied in various research studies. Gafsi and Bakari [18] explored the nexus between renewable energy, CO_2 emissions, and economic growth, and how financial and environmental drivers influence macroeconomic performance.

Similarly, LIBOR is a benchmark financial metric that influences economic indicators such as interest rates and credit markets.

In the digitalization and Financial Innovation financialization of money is transforming economic institutions worldwide. Hlali and Gfasi [19] examined how digitalization is positively impacting sustainable development in Africa with a specific emphasis on its role in financial innovation. The transition from LIBOR to replacement benchmarks such as SOFR is one aspect of the broader trend of financial digitization and innovation aligning with the trends of emerging economies.

3. Research Statement, Data and Methodology

This section comprises three main components. First, we will present the research statement, which highlights the study's objective, scope, and the specific issue under investigation. Second, we will present the data and supporting materials used to construct the study's framework and address the research question while explaining our reasoning behind the choice of the variables. This will also include details on the time period considered. Lastly, we will elaborate on the methodology employed to carry out the study, discussing the model, variables, and econometric tests applied. The following and final step involves analyzing and interpreting the regression findings.

3.1. Research Statement

This research delves into the intricate dynamics of the U.S. banking sector, with a particular focus on the Dow Jones U.S. Banks Index (DJUSBK) as an indicator of its performance. Drawing inspiration from previous work by Professor Kilian Bachmair, we aim to comprehensively assess the significance of selected financial metrics and specific events, such as the LIBOR scandal and its discontinuation, on the DJUSBK index. Our study employs a range of analytical methodologies, including multiple linear regression analysis and correlation matrix examination, to uncover the sector's responsiveness to these external forces. This research contributes to a deeper understanding of how financial metrics and significant events shape the performance of the banking sector, offering invaluable insights for financial analysts, policymakers, and investors in the ever-evolving landscape of banking and finance.

3.2. Data

Reasoning of Choice: The data used in our research is essential for our goal of assessing the significance of key events in the LIBOR scandal and transition on the banking sector:

3.2.1. LIBOR Data

LIBOR, often dubbed the "world's most important number," serves as a fundamental benchmark for global interest rates. It directly impacts banks' borrowing costs, making it a critical factor in their profitability. Analyzing historical LIBOR data allows us to trace how fluctuations in this benchmark rate affect the financial health and performance of banks. Any anomalies or sharp movements could signal a broader issue in the banking sector.

3.2.2. Dow Jones U.S Banks Index

Utilizing the Dow Jones U.S. Banks Index (DJUSBK) as a dependent variable and a key metric in our study is a strategic choice aligned with our research objectives for several compelling reasons. We see that the DJUSBK is a well-established and widely recognized financial index that accurately represents the performance of the banking sector in the United States. It comprises major banks and financial institutions, offering a comprehensive view of the industry's health. This alignment with the banking sector ensures that our study focuses on a relevant and critical segment of the financial markets. Furthermore, investors often use the DJUSBK as a benchmark to assess the performance of their banking-related investments. By analyzing the factors influencing this index, our research provides valuable insights that directly impact investment decisions in the banking industry. In addition to that, the DJUSBK reflects market sentiment and investor confidence in the banking sector. Any significant impact on this index can be indicative of broader market sentiments toward financial institutions. Hence, our study's findings can shed light on how external events and financial metrics affect market perceptions of the sector. Moreover, as the banking industry is subject to rigorous regulatory oversight, understanding the impact of significant events and financial metrics on the DJUSBK can offer insights into how regulatory changes affect the sector's performance. This is particularly relevant when assessing the aftermath of events like the LIBOR scandal and transition.

3.3. The CBOE VIX Index

Incorporating the VIX (CBOE Volatility Index) as an independent variable in our research proves advantageous, as the VIX, often dubbed the "fear gauge" or "market volatility index," gauges the anticipated fluctuations in the stock market. For our study, this metric holds significance because banks and financial institutions closely track market volatility. It directly influences their trading decisions, risk assessments, and overall financial health. By including the VIX as a predictor, we can evaluate how shifts in market sentiment and volatility impact the banking sector. Moreover, banks prioritize risk management as a cornerstone of their operations. The VIX essentially mirrors market risk and uncertainty levels. By integrating the VIX into our analysis, we can scrutinize whether banks react to heightened market risk by modifying their strategies, capital allocation, or risk management methodologies. Additionally, alterations in market volatility often coincide with substantial macroeconomic events or news releases. By factoring in the VIX, our model can encapsulate the broader economic landscape in which the banking sector operates. For instance, spikes in the VIX may

align with economic crises or geopolitical developments that wield substantial influence over banks. Furthermore, banks might dynamically adjust their operations in response to shifts in market volatility. They could recalibrate lending practices, investment strategies, or hedging tactics when market turbulence escalates. By encompassing the VIX as an independent variable, our research endeavors to uncover evidence of such dynamic responses.

Figure 1.
DJUSBK Price over time.
Source: Investing.com

3.3.1.Overview of Gold Prices

Using gold prices as an independent variable in our research is mainly due to the fact that gold prices can reflect market sentiment and risk aversion. During times of uncertainty or economic turmoil, investors often flock to gold as a safe investment. Thus, gold prices can serve as a proxy for investor sentiment and risk appetite, which can impact the dependent variable. Gold prices can be influenced by various global economic indicators, such as central bank policies, geopolitical events, and trade tensions. Including gold prices can help capture the broader economic environment since gold is considered a safe-haven asset, as it tends to have a low correlation with other assets like stocks and bonds. By including gold as an independent variable, we introduce diversification into our analysis.

3.3.2. Event Dates and Event Dummy Variables

The chosen event dates, '2012-06-27' and '2017-07-27,' are pivotal moments in the LIBOR timeline. The first event marked a turning point in regulatory scrutiny, while the second signaled the impending discontinuation of LIBOR. Event dummy variables ('Event1_Dummy' and 'Event2_Dummy') are invaluable tools for isolating the specific impact of these events on the banking sector. They help us discern whether these moments led to statistically significant shifts in bank performance.

Table 1.
Dummy Variables Introduction.

X	Event1_Dummy	Event1_Dummy
Event1 (27-06-2012)	1	0
Event2 (27-07-2017)	0	1

The data is based on daily reports and it covers a time period of over 11 years, from May 2010 to September 2020, providing a comprehensive view of the performance dynamics and macroeconomic conditions over the years. In essence, these variables are the building blocks of our research. They help us decipher the intricate relationship between the LIBOR scandal and transition, market dynamics, and the banking sector's well-being. By examining these data points, we aim to provide a clearer understanding of how these critical events have impacted the banking landscape in the U.S. Furthermore, the LIBOR scandal and transition were chosen as the focus of this study due to the significant and radical change they

present to the financial world and their role in promoting innovation and transparency. The banking sector in the U.S. encompasses a wide range of large international banks and prominent financial institutions globally. By selecting the Dow Jones U.S. Banks Index as our dependent variable, we can safely assess the impact of our chosen event on the banking sector in relation to the chosen variables. The selection of these variables was based on their focus on the financial sector as a whole and also on the banking sector specifically, as well as the availability of reliable data that includes the events we are using in our research.

4. Methodology

In order to investigate the relationship between the independent variables and the chosen dependent variable (Dow Jones U.S. Banks Index), a rigorous statistical analysis using the programming language Python was conducted. Our analysis's goal was to determine the impact of the LIBOR scandal and transition-related events on the U.S. banking sector.

A multiple linear regression model was employed to assess the relationship between the dependent variable (Dow Jones U.S Banks Index) and the independent variables. The regression model can be expressed as follows:

$$DJUSBK = \beta_0 + \beta_1 LIBOR + \beta_2 Gold + \beta_3 VIX + \beta_4\ Event1\_Dummy + \beta_5 Event2\_Dummy + \varepsilon$$

Where:

- LIBOR represents the daily 3Month LIBOR rates
- Gold denotes the daily global price of gold.
- VIX represents the CBOE VIX volatility index.
- Event1_Dummy represents the dummy variable used for the first event (27-06-2012).
- Event2_Dummy represents the dummy variable used for the second event (27-07-2017)
- β_0, β_1, β_2, β_3, β_4 and β_5 represent the regression coefficients.
- ε represents the error term.

We will test the following hypothesis represented in Table 1:

Table 2.
Hypotheses Table.

Independent Variable	Null Hypothesis (H0)	Alternative Hypothesis (H1)
LIBOR	H0: LIBOR has a statistically significant impact on fund's return	H1: LIBOR has no statistically significant impact on fund's return
Gold	H0: Gold prices have a statistically significant impact on fund's return	H1: Gold prices have no statistically significant impact on fund's return
VIX	H0: VIX has a statistically significant impact on fund's return	H1: VIX has no statistically significant impact on fund's return
Event1_Dummy	H0: Event1 has a statistically significant impact on fund's return	H1: Event1 has no statistically significant impact on fund's return
Event2_Dummy	H0: Event2 has a statistically significant impact on fund's return	H1: Event2 has no statistically significant impact on fund's return

Various statistical tests will be conducted to assess the significance and fit of the regression model. Employing hypothesis testing using p-values will determine the statistical significance of each coefficient of our regression analysis, with a significance level (e.g., 0.01, 0.05, 0.1) indicating the strength of the relationship between the independent variable and the DJUSBK, as well as the significance of the impact of the chosen events on the dependent variable.

Furthermore, individual t-tests will be performed to evaluate the significance of each regression coefficient, providing insights into the reliability of the estimated coefficients. The overall goodness of fit of the regression model will be assessed through the R-squared and Adjusted R.

Moreover, diagnostic tests such as the Augmented Dickey-Fuller (ADF) test and the Breusch-Pagan test will be conducted to evaluate model assumptions, including stationarity and heteroscedasticity. These tests are used to ensure the validity and reliability of the regression analysis.

The interpretation of the regression results will be based on the significance of the regression coefficients determined by the p-values. The sign and scale of the coefficients will be examined to understand the relationship between the DJUSBK and the independent variables.

Table 3.
Summary of Key Variables in the Study.

Variable	Min.	Max.	Mean	Std Dev.	Median
DJUSBK	4.975	6.263	5.735	0.314	5.743
LIBOR	0.222	0.284	0.009	0.875	0.47
VIX	9.14	82.69	17.642	7.466	15.54
Gold	1050.8	2051.5	1378.56	196.608	1310.8

Table 7 shows the descriptive statistics of our summary. It can be seen that all the variables are presented in decimal format. All the independent variables showed that their mean is almost the same as their median, which proves the absence of any outliers. Moreover, the kurtosis for the VIX index is remarkably higher than 3, which proves that they aren't normally distributed. In addition, the DJUSBK, LIBOR, and Gold variables showed a negative skewness, proving that they are left skewed. On the other hand, all the remaining variables were right-skewed.

Table 4.
Independent Variables Correlation Matrix.

Ind. Variables	LIBOR	Gold	VIX	Event1_dummy	Event2_Dummy
LIBOR	1				
Gold	-0.168	1			
VIX	-0.126	0.380	1		
Event1_Dummy	-0.066	0.139	0.03	1	
Event2_Dummy	0.071	-0.082	-0.114	-0.017	1

The correlation matrix above, as presented in Table 8, provides crucial insights into the relationships between the variables. Notably, there is a weak negative correlation (-0.168) between the London Interbank Offered Rate (LIBOR) and Gold, suggesting that as LIBOR rates increase, Gold prices tend to decrease slightly. This might indicate a tendency for investors to reallocate their funds from Gold to interest-bearing assets during periods of higher LIBOR rates. Moreover, a moderate positive correlation (0.38) is observed between Gold and the Volatility Index (VIX). When Gold prices rise, the VIX tends to increase as well, implying that Gold is perceived as a safe-haven asset during market volatility. In contrast, LIBOR exhibits a weak negative correlation with the VIX, implying that higher LIBOR rates are associated with decreased market volatility.

Moving to the interpretation of the correlation coefficients between the event dummy variables (Event1_Dummy and Event2_Dummy) and the independent variables (LIBOR, Gold, and VIX) considering the specific events, we see that with the knowledge that Event1 corresponds to the LIBOR scandal in 2012 and Event2 is associated with the discontinuation of LIBOR in 2017, the correlations take on a more meaningful interpretation. The negative correlation of approximately -0.066 between LIBOR and Event1_Dummy suggests that LIBOR rates were slightly lower when the LIBOR scandal occurred. This aligns with expectations, as the scandal involved manipulations that could have artificially inflated LIBOR rates. The positive correlation of approximately 0.071 between LIBOR and Event2_Dummy indicates a minor tendency for LIBOR rates to increase when the announcement of LIBOR discontinuation took place. This is reasonable, as such an announcement could lead to changes in market perceptions and borrowing costs. The positive correlation of approximately 0.139 between Gold and Event1_Dummy now signifies a weak tendency for Gold prices to increase during the LIBOR scandal in 2012. This aligns with the historical trend of investors turning to gold as a safe-haven asset during times of financial uncertainty. Conversely, the negative correlation of approximately -0.082 between Gold and Event2_Dummy suggests that Gold prices exhibited a minor decrease when the LIBOR discontinuation was announced in 2017. This may indicate reduced demand for safe-haven assets as markets adjusted to the change in benchmark rates. The extremely weak positive correlation of approximately 0.03 between VIX and Event1_Dummy suggests a minor increase in market volatility during the LIBOR scandal. Similarly, the weak negative correlation of approximately -0.114 between VIX and Event2_Dummy implies a slight decrease in market volatility when the announcement of LIBOR discontinuation occurred. These correlations indicate limited market reactions to these specific events. We can safely say that with the provided context, it becomes apparent that the correlations between the event dummy variables and the independent variables are more aligned with expectations. Event1, linked to the LIBOR scandal, coincides with LIBOR rate decreases and gold price increases, while Event2, associated with LIBOR discontinuation, corresponds to LIBOR rate increases and gold price decreases. These correlations suggest that these events had some influence on these financial indicators, albeit with relatively weak linear relationships.

Table 5.
Econometric Tests.

Test	P-Value	Test statistic
Augmented Dickey Fuller	0.5689	N/A
Breusch Pagan	0.000	1.32

Augmented Dickey-Fuller (ADF) Test: The p-value for the ADF test is 0.5689, which is greater than the typical significance level of 0.05. This suggests that you fail to reject the null hypothesis. In other words, there is insufficient evidence to conclude that the data has a unit root, which means the data may not be stationary. A higher p-value indicates non-stationarity. We use the visualization of the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots of the DJUSBK Series.

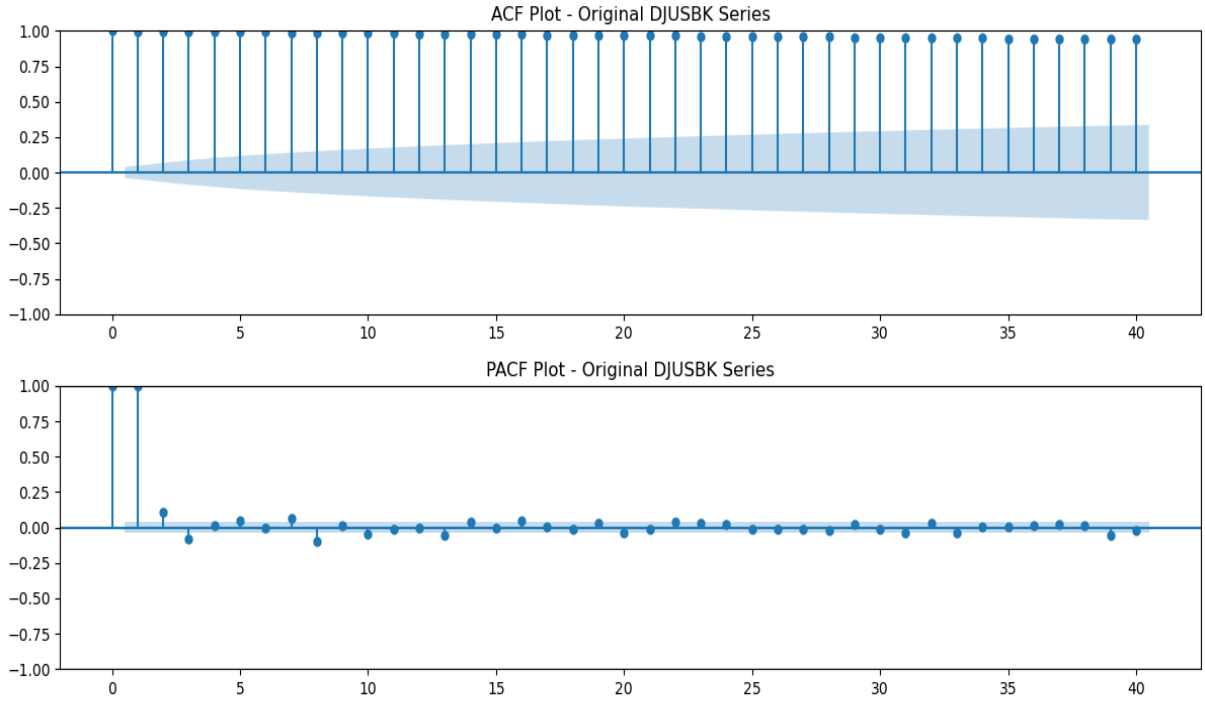

Figure 2.
Visualization of the ACF and PACF Plots of the DJUSBK series

The ACF plot shows the correlation between a time series and its lagged values (previous observations). Our ACF plot shows significant correlations that decrease gradually as lag increases (a slow decay). This also suggests that the time series may not be stationary. In this case, differencing may be necessary.

The PACF plot shows the partial correlation between a time series and its lagged values after removing the effects of shorter lags. Although a PACF plot with significant spikes at specific lags (e.g., lag 1 or 2) and no significant partial correlations beyond those lags usually indicates a stationary time series, with the ADF test and the ACF plot, we have enough evidence and motive to believe that our data is not stationary.

Due to these results, we decided to use the differencing method, which is a technique to transform a non-stationary time series into a stationary one. It involves subtracting the current value of the series from the previous one. We conduct differencing with order 1, which is a fundamental operation in time series analysis. This mathematical technique involves subtracting each observation at a specific time point (Y(t)) from the previous observation (Y(t-1)). The primary effect of applying first-order differencing to a time series is the removal of any linear trends or growth/decay patterns present in the data.

Table 6.
Stationarity ADF Test Results after Differencing

Test (After Differencing once)	P-Value
Augmented Dickey Fuller	0.000

After using fist-order differencing, the previous P-value 0.5689 has dropped to 0.000 < 0.05. This proves that according to the ADF test we can safely assume that our series has become stationary.

After first-order differencing the significant correlations observed at lag 1 in ACF plot indicate that the current observation is highly correlated with the previous one, which is expected after differencing. However, the sharp drop in correlations beyond lag 1 suggests that there is no substantial temporal dependence left in the data after differencing. In other words, the first-order differencing has effectively removed any autocorrelation structure, making the data more stationary. Additionally, the significant spike at lag 1 in the PACF plot indicates a strong direct influence of the previous observation on the current one. The sharp decline in partial correlations after lag 1 suggests that there is no significant direct influence from observations further back in time. This is consistent with the idea that the first-order differencing has removed most of the temporal dependence in the data.

Breusch-Pagan Test: As seen in Table 4, the test statistic for the Breusch-Pagan test is 1.32, which is the measure of evidence for heteroskedasticity. A larger test statistic indicates more evidence in favor of heteroskedasticity. The p-value for the Breusch-Pagan test is 0.000, which is less than the significance level of 0.05. This indicates that we can reject the null hypothesis. In this case, the null hypothesis is that there is no heteroskedasticity (constant variance of the error terms). Since the p-value is very low, it suggests strong evidence of heteroskedasticity. Since we are in violation of the fundamental assumption that the errors (residuals) in our regression analysis are independently and identically distributed (i.i.d.) with constant variance (homoscedasticity), and in order to ensure the validity of our data, we employ the Generalized Least Squares (GLS) technique called the Standard Robust Error in our model. The "Standard Robust Error"

technique, which is often referred to as heteroskedasticity-robust standard errors or White-corrected standard errors, is a statistical tool that comes in handy when conducting regression analysis. Its purpose is to address a common issue in regression: the assumption of homoscedasticity. The Standard Robust Errors in the GLS model acknowledge the possibility of heteroskedasticity and adjust the standard errors of the regression coefficients accordingly. It provides more accurate and reliable estimates, considering the varying error variances. In our research, where we are assessing the impact of key events in the LIBOR scandal and transition on the banking sector, it is critical to account for potential changes in the volatility of DJUSBK prices around these events. Using robust standard errors ensures that our statistical analyses are valid, even when heteroskedasticity is present.

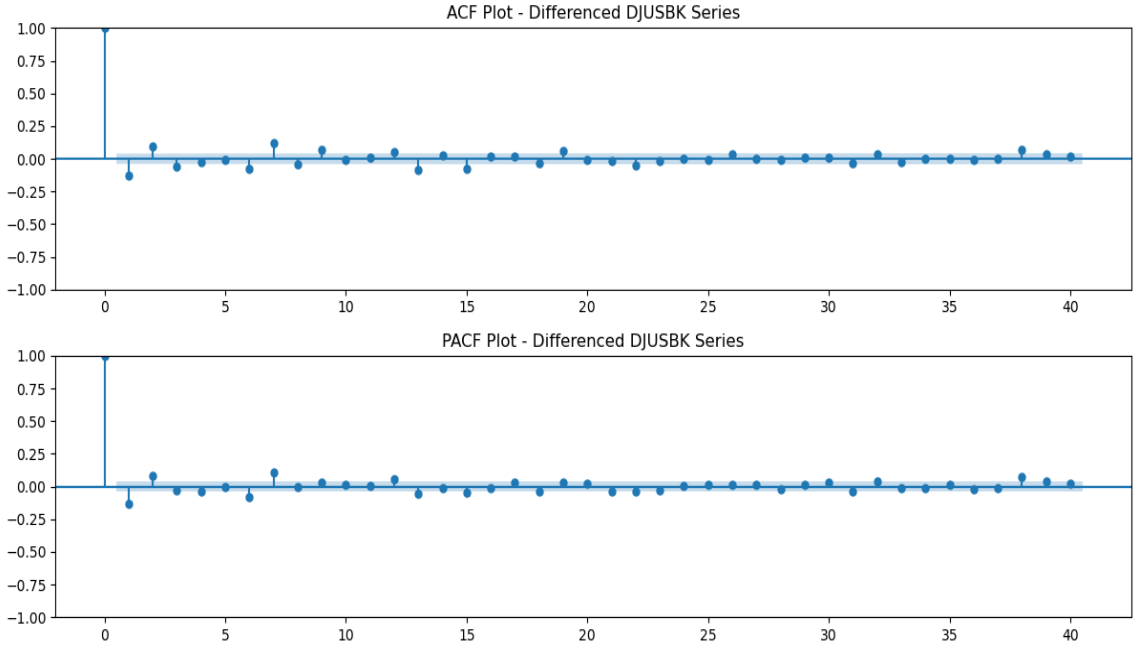

Figure 3.
Visualization of the ACF and PACF Plots of the DJUSBK series after first-order differencing.

Table 7.
Results of Variance Inflation Factor (VIF) Test for multicollinearity.

Independent Variable	Variance Inflation Factor (VIF)
LIBOR	2.093
VIX	7.799
Gold	9.369
Event1_Dummy	1.028
Event2_Dummy	1.029

The Variance Inflation Factor (VIF) measures the extent of multicollinearity among the independent variables in a regression model. In our analysis, the VIF values shed light on the relationships between specific variables. LIBOR exhibits a relatively low VIF of 2.092592, indicating a modest degree of multicollinearity with other independent variables. Conversely, VIX displays a moderate level of multicollinearity, with a VIF of 7.799301, implying stronger correlations with other model predictors. Gold stands out with the highest VIF at 9.369648, signaling a notable level of multicollinearity, meaning its coefficient's variance is significantly influenced by interactions with other variables. In contrast, the dummy variables, Event1_Dummy and Event2_Dummy, present VIF values close to 1 (1.028801 and 1.029663, respectively), suggesting minimal multicollinearity with other independent variables. This aligns with expectations, as dummy variables typically represent categorical factors and do not strongly correlate with continuous variables like LIBOR, VIX, and Gold. These VIF findings provide valuable insights into the interplay between variables in our regression model, guiding us in assessing their independent contributions and potential collinearities. Since all VIF values for the independent variables are less than 10, we can safely assume that the validity of our data is still intact.

Table 8.
Regression General Findings

Ind. Variables		Regression Analysis	
Ind. Var	Significant Ind. Var.	R squared	Adjusted R squared
5	5	0.979	0.9786

Table 8 reveals that all five independent variables utilized in the analysis are deemed statistically significant, indicating that each of them possesses a meaningful relationship with the dependent variable. The high R-squared value of 0.979 signifies that 97.9% of the variation in DJUSBK values can be elucidated by these independent variables. Furthermore, the adjusted R-squared value of 0.9786, which considers the model's complexity, reinforces the conclusion that the model is well-constructed and that the independent variables collectively exert substantial explanatory power over DJUSBK prices.

Table 9.
Explanatory Variables Results

Independent Variable	Coefficient	T-statistic	P-Value
LIBOR	0.572	28.08	0.000***
VIX	-0.011	-4.337	0.000***
Gold	0.004	105.196	0.000***
Event1_Dummy	-0.951	-7.138	0.000***
Event2_Dummy	0.564	4.336	0.000***

Note: Significant at 0.1 *, Significant at 0.05 **, Significant at 0.01 ***.

The Table 9 presents the outcomes of a multiple linear regression analysis, detailing the coefficients, t-statistics, and p-values for each independent variable within the model. Starting with LIBOR (London Interbank Offered Rate), the coefficient of approximately 57.23 implies that as LIBOR increases, the corresponding dependent variable (likely DJB) tends to rise. Signifying a robust relationship, the high t-statistic of 28.08 and an extremely low p-value (close to zero) emphasize the statistical significance of this link. Similarly, VIX (Volatility Index) exhibits a negative coefficient of approximately -0.0105, suggesting that a rise in VIX, indicating increased market volatility, tends to lead to a decrease in the dependent variable. The significant t-statistic of -4.34 and a low p-value (close to zero) reiterate the statistical significance. Meanwhile, the Gold variable showcases a coefficient of approximately 0.0039, implying that an increase in Gold price correlates with an increase in the dependent variable. Notably, the exceptionally high t-statistic of 105.20 and a p-value of zero highlight the robust statistical significance of this relationship.

Event1_Dummy, marked by a significant negative coefficient, implies that the occurrence of the LIBOR scandal in 2012 was associated with a noteworthy adverse impact on the Dow Jones Banks Index (DJUSBK). This aligns with the adverse consequences, including regulatory scrutiny and potential reputational damage, that financial institutions like Barclays faced during the scandal. The high absolute T-statistic and the near-zero p-value underscore the statistical robustness of this finding. Conversely, Event2_Dummy, which exhibits a substantial positive coefficient, suggests that the FCA's announcement of LIBOR discontinuation in 2017 had a substantial favorable influence on the DJUSBK. This is consistent with the positive sentiment and stability brought by the transition to alternative reference rates, removing uncertainties associated with the old LIBOR framework. The strong T-statistic and low p-value reiterate the statistical significance of this relationship.

5. Conclusion and Recommendations

5.1. Conclusion

In this comprehensive study, we have embarked on a profound exploration of the multifaceted dynamics within the U.S. banking sector, with a keen focus on the Dow Jones U.S. Banks Index (DJUSBK) as a representative indicator. Our research was inspired by the seminal work of Professor Kilian Bachmair, which provided the groundwork for an in-depth analysis of how financial metrics and event-related dummy variables shed light on the sector's responsiveness to external forces.

The multiple linear regression analysis presented a wealth of insights into the relationships between independent variables and the DJUSBK index. LIBOR, a fundamental financial benchmark, exhibited a robust positive relationship with DJUSBK, indicating that as LIBOR rates increased, the index tended to rise. Similarly, the Volatility Index (VIX) displayed a significant negative relationship, suggesting that higher market volatility, as indicated by an increased VIX, corresponded to a decrease in the DJUSBK. The daily gold prices exhibited a particularly strong positive relationship with the DJUSBK, emphasizing the pivotal role of precious metals in influencing the banking sector.

Our exploration of specific events within the banking sector unveiled compelling findings. Event1_Dummy, signifying the 2012 LIBOR scandal, was associated with a substantial adverse impact on DJUSBK, aligning with the regulatory scrutiny and reputational damage faced by financial institutions during the scandal. Conversely, Event2_Dummy, representing the 2017 announcement of LIBOR discontinuation, exerted a substantial favorable influence on DJUSBK, coinciding with the industry's transition to alternative reference rates and the removal of uncertainties associated with the old LIBOR framework. These findings underscore the statistical significance and real-world implications of these events within the banking sector.

Our correlation matrix analysis provided further insights into the relationships between variables. Notably, we observed a weak negative correlation between LIBOR and gold, suggesting a tendency for investors to reallocate their funds from gold to interest-bearing assets during periods of higher LIBOR rates. Additionally, a moderate positive correlation between gold and the VIX indicated that gold is perceived as a safe-haven asset during market volatility. Furthermore, the correlation coefficients between the event dummy variables and independent variables, when considered in the context of specific events, provided meaningful interpretations. Event1, associated with the LIBOR scandal, coincided with LIBOR rate decreases and gold price increases, while Event2, linked to LIBOR discontinuation,

corresponded to LIBOR rate increases and gold price decreases. These correlations suggested that these events had discernible, albeit relatively weak, influences on these financial indicators.

In conclusion, this study deepens our understanding of the intricate relationships within the U.S. banking sector. It underscores the significance of financial metrics, such as LIBOR rates, VIX volatility, and gold prices, in shaping the sector's performance. Moreover, it confirms the substantial impact of specific events, offering valuable insights for financial analysts, policymakers, and investors seeking to navigate the ever-evolving landscape of banking and finance.

5.2. Recommendations

In concluding this study, it is vital to acknowledge its limitations and chart potential paths for further research within the dynamic realm of the U.S. banking sector. First and foremost, expanding the dataset to include more recent data beyond September 2020 is advisable, considering the rapid changes witnessed in the financial landscape. Additionally, further event analysis can enhance our understanding of how the sector responds to various challenges, necessitating the inclusion of significant events that have shaped the industry. To provide a more holistic perspective, incorporating a broader set of macroeconomic variables, such as interest rates, inflation, and GDP growth, is recommended as these factors intimately intertwine with the banking sector's performance. Leveraging advanced machine learning techniques for predictive modeling can unlock nonlinear patterns, offering valuable insights into future trends and risks. Furthermore, exploring the impact of ethical and environmental, social, and governance (ESG) considerations on the banking sector is increasingly pertinent in today's ethical investment landscape. Comparative cross-border analyses and longitudinal studies tracking individual banks over time can provide both macro and micro-level insights into sector dynamics. In amalgamation, addressing these recommendations ensures that future research endeavors continue to illuminate the intricate workings of the U.S. banking sector, benefiting researchers, policymakers, and industry stakeholders alike.

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