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Revisiting the interest rate, foreign exchange rate, and bank stock return nexus in Saudi Arabia: evidence from the wavelet approach

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Abstract: This study analyzes the relationship between interest rates, exchange rates, and the bank stock return in Saudi Arabia. We use both traditional and novel wavelet analyses to revisit how these macroeconomic variables interact and influence each other in short-, mid-, and long-term periods, and during specific crisis events such as the COVID-19 pandemic and the Ukraine-Russia conflict. The results reveal that all the variables are significantly related in the long and short term, while the interaction among the variables differs over time and frequency domains. In particular, interest rates displayed high volatility during COVID-19, while exchange rates and the banking index showed lower volatility. In addition, interest and exchange rates demonstrated a positive correlation and increased volatility from 2018 to 2020, with the return of the banking index taking a leading position during the COVID-19 pandemic. Overall, this study highlights the risks and opportunities for Saudi Arabia's distinctive dual banking system arising from macroeconomic fluctuations. Policymakers, regulators, and bankers can utilize these insights to make informed strategic and operational decisions regarding their approach to the country's dynamic economic environment and distinct banking landscape.

Keywords: Saudi Arabia, Saudi banks, Interest rate, Foreign exchange, Wavelet analysis.

إعادة النظر في العَلاقة بين سعر الفائدة وسعر صرف العملات الأجنبية وعوائد أسهم البنوك في المملكة العربية السعودية: منهجية تحليل الموجات

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المستخلص: تحلل هذه الدراسة العَلاقة بين أسعار الفائدة وأسعار الصرف وعائد أسهم البنوك في المملكة العربية السعودية. نحن نستخدم تحليلات الموجات التقليدية والجديدة لإعادة النظر في كيفية تفاعل متغيرات الاقتصاد الكلي هذه وتأثيرها على بعضها البعض، في فترات قصيرة ومتوسطة وطويلة الأجل، وخلال أحداث أزمات محددة مثل جائحة كوفيد-19 والأزمة الأوكرانية الروسية. أظهرت النتائج أن جميع المتغيرات ترتبط ارتباطاً وثيقاً على المدى الطويل والقصير، في حين يختلف التفاعل بين المتغيرات على مدى الزمن والمجالات التكرارية. وعلى وجه الخصوص، أظهرت أسعار الفائدة تقلبات عالية خلال أزمة كوفيد-19، في حين أظهرت أسعار الصرف والمؤشر المصرفي تقلبات أقل. إضافة إلى ذلك، أظهرت أسعار الفائدة وأسعار الصرف ارتباطًا إيجابيًا وزيادة في التقلبات من عام 2018 إلى عام 2020، مع عودة المؤشر المصرفي ليحتل مكانة رائدة خلال جائحة كوفيد-19. عمومًا، تسلط هذه الدراسة الضوء على المخاطر والفرص التي يواجهها النظام المصرفي المزدوج المميز في المملكة العربية السعودية والناجمة عن تقلبات الاقتصاد الكلي. يمكن لواضعي السياسات والمنظمين والمصرفيين الاستفادة من هذه الأفكار لاتخاذ قرارات استراتيجية وتشغيلية مستنيرة فيما يتعلق بنهجهم تجاه البيئة الاقتصادية الديناميكية للبلاد والمشهد المصرفي المتميز.

الكلمات المفتاحية: المملكة العربية السعودية، البنوك السعودية، سعر الفائدة، سعر صرف العملات الأجنبية، تحليل الموجات.

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1. Introduction

Ross (1976) proposed the Arbitrage Pricing Theory (APT), which assumes that several systematic factors, in addition to the market factor, are responsible for the substantial variation in stock returns. Several systematic factors have been shown to be empirically associated with stock returns. These factors include fluctuations in interest rates, exchange rates, inflation rates, the industrial production index, gold prices, oil prices, etc. However, capital flows, which can affect a country's economic growth, are strongly influenced by the performance of the stock market and macroeconomic variables such as foreign exchange and interest rates (Aydemir & Demirhan, 2017). The Saudi Arabian Capital Market Authority (CMA) aims to increase foreign investment in Saudi equity markets. In 2016, the CMA amended the rules governing investments by foreign financial institutions in listed securities. Foreign ownership has increased by 51.33% of the average annual return from USD 26.67 billion in 2019 to USD 92.43 billion in 2022. However, apart from the fact that banks' performance depends on the movements in interest and exchange rates, Saudi banks have the greatest influence on the overall Saudi market index. The Saudi Arabian banking sector operates under a dual banking system in which both conventional and Islamic banks coexist and compete, with assets of USD 965.59 billion in 2022. The Islamic Financial Services Board (2023) reports that Saudi Islamic banks' assets account for 30.6% of the global Islamic banking market, making Saudi Arabia home to the largest Islamic bank in the world (Al-Rajhi Bank). The Saudi Stock Exchange, also known as Tadawul, is a major capital market, ranking among the ten largest in the world. As of the end of 2022, its market capitalization totalled USD 2,634.16 billion.

The relationship between fluctuations in interest rates, foreign exchange, and bank stock returns has been studied in the literature from a time domain perspective, using a variety of time series methods. These methods vary from typical OLS regression analysis to more advanced techniques such as ARCH/GARCH and vector autoregressive (VAR) models. However, although there have been significant improvements in modelling methods, the potential impact of factors such as the investment period on the relationships between interest rates, foreign exchange, and stock market returns has been overlooked. The behaviour of the overall market is determined by the choices made by thousands of diverse agents across a range of time periods (from seconds to years) in financial security markets like the bond and stock markets. According to Moya-Martínez et al. (2015), day traders, who have a short investment horizon, often speculate and make decisions based on transitory events such as earnings surprises, merger announcements, market sentiment, and psychological considerations, while long-term investors such as large institutional investors invest more actively and study macroeconomic factors such as the business cycle, inflation, monetary policy, and so on. In this situation, the wavelet method, which considers both the time and frequency domains simultaneously, appears to be an extremely attractive option. Unlike time-domain methods that combine all time horizons, wavelet analysis is a relatively new and powerful signal processing tool, at least in the context of finance, that offers a unique opportunity to study the interdependence between financial time series in time-frequency space (Ferrer et al., 2016).

In this study, a wavelet coherence analysis and a spectrum-variance wavelet analysis are used to examine the relationship between changes in interest rates, exchange rates, and the Saudi banking index. The main research question of the study is whether and how the investment horizon affects the relationship between interest rates, exchange

rates and the Saudi banking index. According to Alsharif (2023), the analysis of the GARCH model showed that the volatility of interest rates and exchange rates significantly increases the volatility of Saudi banks' returns. However, according to Grinsted et al. (2004), the use of wavelet analysis allows the study of coherence and co-movements across different frequencies and time horizons. Wavelet analysis can detect relationships between financial time series at different time intervals and cyclical components (frequencies), giving regulators and traders insight into how these relationships form and evolve over time, not just whether or not they exist (Almaskati, 2022). The strength and pattern of linkages can change over time, so wavelet analysis provides a more nuanced and time-varying view of interdependencies compared to traditional approaches. This can help regulators with surveillance, managers with hedging and risk management, and traders with exploiting potential opportunities. In short, wavelet analysis provides a valuable tool for revealing timescale-dependent relationships in economic and financial data.

This study extends previous research in several ways. First, to the authors' knowledge, this is the first study to analyze the relationship between interest rate, exchange rate, and the banking index in Saudi Arabia using wavelet analysis. Second, the study focuses on an emerging market country with the largest dual banking system in the world. Third, the study includes four measures of interest rates and high-frequency daily data from 2016 through 2022 to strengthen the robustness of the findings. Finally, the study provides new insights into the risks and opportunities arising from the macroeconomic fluctuations that Saudi banks face. The findings could help policymakers, regulators, and banking executives assess vulnerabilities, adjust risk management, and make strategic decisions regarding operations in Saudi Arabia's distinct dual banking system and economy.

The following is the structure of the study: Section 2 discusses the previous literature, while Section 3 explains the research methodology and data. The empirical results are addressed in Section 4. The study's key findings are summarized and outlined in Section 5.

2. Literature review

The Efficient Market Hypothesis (EMH) states that any event that affects a company's cash flow is accurately reflected in its stock prices. According to Reilly and Brown (2011), the rapid spread of information in markets results in stock prices that are expected to comprehensively and precisely reflect all available information, both past and present. Therefore, several studies have examined the relationship between interest rates, exchange rates, and bank stock returns using different methods. The impact of interest rate changes on 56 banks in the United States was studied by Mansur and Elyasiani (1995). The study used the ARCH model and analyzed data from 1979 to 1992. Long-term interest rates were found to have a more significant negative impact on bank stock returns than their shorter-term counterparts. In addition, Elyasiani and Mansur (1998) used the GARCH-M model to evaluate how changes in interest rates and volatility at U.S. banks affect bank stock returns. The study revealed that there is a statistically significant negative relationship between interest rate returns and bank stock returns. Additionally, an increase in interest rate volatility was found to be associated with a decrease in bank stock volatility. Paul and Mallik (2003) conducted a study in Australia for the period 1980 to 1999, performing macroeconomic analysis and examining variables such as inflation, interest rates, and GDP. The study employed

cointegration tests and an error correction model to investigate the long-term association between macroeconomic variables and the return of banking and finance stock prices. The findings of the study indicate that there is a cointegration between banking and finance stock returns and the three macroeconomic factors. The influence of interest rates was negative, while the influence of GDP growth was positive. However, the influence of inflation on stock returns was found to be insignificant. Additionally, Mouna and Anis (2016) used the GARCH extension model to examine the relationship between macroeconomic variables (market yields, interest rates, and exchange rates) and the returns on stock of financial institutions in eight different markets from 2006 to 2009. For German, U.S., and Italian banks, exchange rates were positively related to their stock returns, whereas for U.K. banks, they were adversely related to their stock returns. In addition, bank stock returns were negatively affected by changes in short-term interest rates in Greece and France, but positively in the United States and Spain. However, it was found that for long-term interest rates, Italian banks significantly experienced a negative effect, whereas American and French banks significantly experienced a positive effect.

However, from an emerging market perspective, using the OLS and GARCH estimating models, Kasman et al. (2011) examined the impact of interest rate and exchange rate fluctuations on Turkish banks' stock returns from 1999 to 2009. They concluded that bank stock volatility is highly correlated with interest rate and exchange rate volatility and that changes in interest rates and exchange rates are negatively associated with Turkish bank stock returns. Using a pooled OLS panel estimator, Nurazi and Usman (2016) analyzed the impact of macroeconomic factors like interest rate, exchange rate, and inflation rate, as well as CAMEL financial ratios, on bank stock returns in Indonesia between 2002 and 2011. All macroeconomic variables were found to have a significant negative effect on Indonesian bank stock returns, although financial parameters had different effects on bank performance. Bui and Nguyen (2021) used a hybrid approach involving Bayesian model analysis with the least-absolute shrinkage and selection operator (LASSO) from 2012 to 2018 to examine the effects of exchange rate and interest rate variables on the performance of bank stocks in Vietnam. The study showed that the impact of interest rates was adverse and statistically significant, while the impact of exchange rates was negligible or nonexistent. Recently, Alsharif (2023) used the GARCH model to analyze stock returns and volatility of Saudi Arabian banks from 2010 to 2019 in light of the effects of changes in exchange rates and interest rates. He pointed out that conventional Saudi banks benefited from higher exchange rate returns, while Islamic Saudi banks suffered. The author also found that Saudi banks' stock returns were positively related to interest rate returns, suggesting that Saudi banks' assets are more sensitive to interest rate fluctuations than their liabilities. Finally, the study found that higher volatility in exchange rates and interest rates led to higher volatility in Saudi banks' returns. Thus, the preceding literature shows that there should be a relationship between interest rates, exchange rates, and bank share prices. The present research, therefore, contributes to the literature by analyzing the relationship between interest rates, exchange rates, and the banking index in Saudi Arabia using wavelet analysis.

3. Methodology

3.1 Data

In this study, we use daily data to explore the dynamic time- and frequency-based short-term, medium-term, and long-term relationships between variables. We also examine the lead-lag or causality relationship between the interest rate, exchange rate, and stock index of the banking sector in Saudi Arabia. In this study, we use a time series of daily data covering the period from January 2016 to December 2022. To the best of our knowledge, the dynamic relationship between the interest rate, exchange rate, and banking sector stock index in Saudi Arabia using the wavelet approach has not been investigated in the existing literature.

3.2 Theoricial underpining

In this study, we investigate the relationship between the interest rate, exchange rate, and stock price return of the banking sector in Saudi Arabia using a dynamic wavelet approach, which is in line with wavelet theory. Wavelet theory provides a mathematical framework that is widely applied in finance literature. Moreover, it provides signals and images based on both physics and economics, in terms of border aspects. It contracts different functions and operates with small waves that are localized in both the time and frequency domains. Unlike the Fourier approach, wavelet has a large

3.3.1 Wavelet variance analysis

The other name for the wavelet power spectrum is wavelet variance analysis. It represents the distribution of the power of a signal across both time and frequency family, commonly known as Daubechies wavelets, Haar wavelets, and Morlet wavelets. However, wavelet transformation contains mainly two forms of continuous wavelet transform, which are shortly called CWT and DWT (e.g. discrete wavelet transform). Wavelet theory contributes in numerous ways to financial literature on time-frequency analysis, decomposing or recomposing with image compression, and signal processing of datasets. Finally, wavelet theory captures a powerful framework for analyzing signals and images at diverse scales and resolutions, making it a valuable tool not only in economics but also in scientific and engineering disciplines (Ali et al., 2021).

3.3 Model specification

In this study, we used wavelet variance and coherence analyses. The advantage of this approach is that it is essentially based on the dynamic properties of the time and frequency domains (Sahabuddin, Hassan, et al., 2022). It is also popular because of its non-parametric nature (Sahabuddin, Islam, et al., 2022). It can overcome the disadvantages of stationarity and non-stationarity of time-series data. Similarly, we can apply this approach to time series raw or non-stationary data, as well as natural log-based stationary data (Mutascu et al., 2022). However, to determine the lead-lag or causal relationship between variables, this approach is often used (Ali et al., 2021; HUNG, 2020; Umar & Gubareva, 2020). In this section, the wavelet approach is briefly discussed.

domains. It computes both the CWT and DWT; however, the wavelet variance formula for the continuous wavelet transform is as follows:

$$Var\ (a) = \int_{-\infty}^{\infty} [w(a,\tau)]^{2}\, d\tau \qquad (1)$$

where, $Var\ (a)$ denotes the wavelet variance, $w(a,\tau)$ exhibits the wavelet transform coefficient for scale a and localization τ. This formula defines the squared magnitude of the wavelet coefficients over all positions. This provides valuable insights into how the power of a signal is distributed across different scales and frequencies. Higher values in the wavelet power spectrum detect regions of the signal that have more power at certain scales and frequencies.

3.3.2 Wavelet coherence analysis

Wavelet coherence analysis is a widespread and popular statistical measure used to quantify the degree of dynamic association between two time series as a function of both time and frequency. It is predominantly useful for analyzing time-varying relationships between non-stationary and stationary data or signals, allowing scholars to identify periods of significant correlation between signals across different frequencies. The formula for the wavelet coherence transform is as follows:

$$WCT_{xy\,(\alpha,\,\tau)} \frac{\left[\, W_x\,(\alpha,\tau)\overline{W_{y\,(\alpha,\tau)}}\,\right]}{\sqrt{P_{x\,(\alpha,\tau)}.P_{y(\alpha,\tau)}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, WCT xy (a,τ) represent the wavelet coherence between signals x(t) and y(t) at scale α and position τ, $W_x\ (\alpha,\tau)$ and $W_{y\,(\alpha,\tau)}$ denotes the wavelet transform coefficient of signals x(t) and y(t) at scale α and position τ respectively. Moreover, $\overline{W_{y\,(\alpha,\tau)}}$ express the complex conjugate of $W_{y\,(\alpha,\tau)}$.

Wavelet coherence also provides a multi-dimensional casual direction between two variables or series. It can be visualized as a two-dimensional plot, where one axis denotes time, while the other axis exhibits frequency or scale. The coherence value ranges from 0 to 1, with higher (lower) values. Higher values indicate a stronger correlation between the signals at the corresponding frequency and time, and a lower value indicates a lower correlation (e.g., better portfolio diversification avenues) between the signals at the corresponding scale and time.

4. Results and discussion

4.1 Preliminary analysis

Data for this study were obtained from the Argaam database. For the interest rate, we used the Saudi Arabia interbank interest rate for 1 month, 3 months, 6 months, and 12 months. We also used data from the Saudi Arabian Banking Index and the Saudi Riyal-to-USD exchange rate. However, our study shows performance movement in response to time horizons. Our study covers two crises (e.g., COVID-19 and the ongoing Ukraine-Russia conflict), which express variation among the variables over the period. Figure 1 shows the time patterns of the interbank rate, banking index, and exchange rate of the riyal to the USD in Saudi Arabia. The results show that COVID-19 and the Ukraine-Russia conflict have significant effects on all variables (Shaik et al., 2023). However, we found that the COVID-19 period has higher volatility than the Russia-Ukraine conflict period (Gaio et al., 2022).

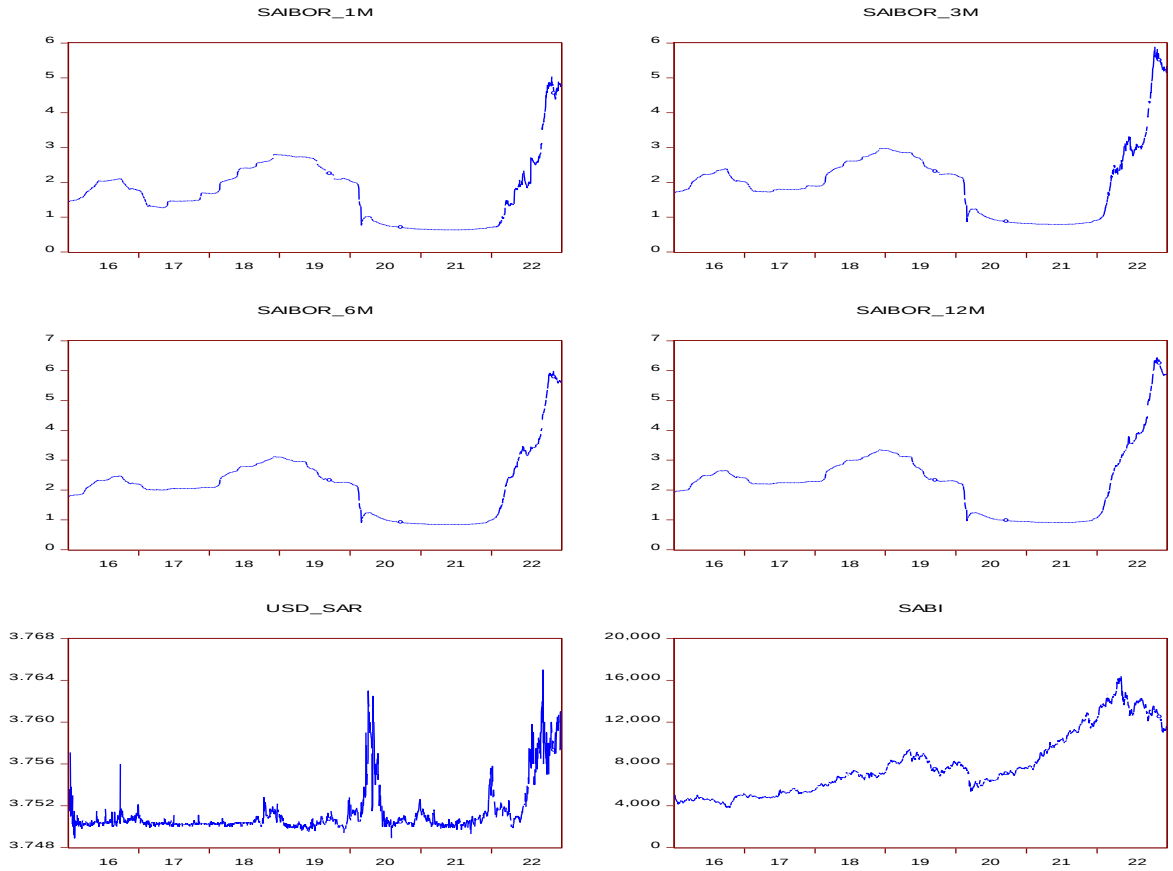


Fig. 1: Time patterns of the varisbles

Note: SAIBOR_1M = Saudi Arabia Interbank interest rate for 1 month; SAIBOR_3M = Saudi Arabia Interbank Rate for 3 months; SAIBOR_6M = Saudi Arabia Interbank Rate for 6 months; SAIBOR_12M = Saudi Arabia Interbank Rate for 12 months; USA/SAR = Saudi Arabia Exchange rate in USD; SABI = Saudi Arabia Bank return.

4.2 Properties of descriptive Statistics

Table 1 presents the descriptive statistics. The results show that the bank index return provides a better mean return, while the 1-month interbank rate has the highest volatility. All the return series reject the properties of a normal distribution at a significance level of 1%. Moreover, all variables rejected leptokurtic properties due to positive skewness, except for the riyal exchange rate. Our study applies the augmented Dickey–Fuller test to determine the stationary and non-stationary properties of all series, and the results show that all variables fulfilled the criteria of stionarity at the 1% significance level. Table 2 presents the results of the correlation matrix of the observed variables. The findings indicate that the exchange rate and bank returns are negatively correlated with interest rates, while the 6-month interbank offered interest rate is strongly correlated with the 12-month interbank offered interest rate.

Table 1: Descriptive statistics

	SAIBOR_1M	SAIBOR_3M	SAIBOR_6M	SAIBOR_12M	USD_SAR	SABI
Mean	-0.0297	-0.0286	-0.0286	-0.0277	0.0000	-0.0206
Std. Dev.	0.8726	0.6715	0.5285	0.4797	0.0081	0.5514

	SAIBOR_1M	SAIBOR_3M	SAIBOR_6M	SAIBOR_12M	USD_SAR	SABI
Skewness	6.7131	12.1880	16.7594	14.5740	-1.7803	0.7319
Kurtosis	311.4127	344.7329	520.6264	426.5408	54.3374	9.8871
Jarque-Bera	6936948.0000	8543963.0000	19585366.0000	13119712.0000	192767.9000	3608.6630
Obs.	1747	1747	1747	1747	1747	1747
ADF	-10.51(-2.86)***	-8.35(-2.86)***	-7.56(-2.86)***	-8.19(-2.86)***	-22.92(-2.86)***	-37.57(-2.86)***

Note: SAIBOR_1M = Saudi Arabia Interbank Offred Rate for 1 month; SAIBOR_3M = Saudi Arabia Interbank Rate for 3 months; SAIBOR_6M = Saudi Arabia Interbank Rate for 6 months; SAIBOR_12M = Saudi Arabia Interbank Rate for 12 months; USA/SAR = Saudi Arabia Exchange rate in USD; SABI = Saudi Arabia Bank Index price.

Table 2: Correlation matrix

	SAIBOR_1M	SAIBOR_3M	SAIBOR_6M	SAIBOR_12M	USD_SAR	SABI
SAIBOR_1M	-					
SAIBOR_3M	0.6766	-				
SAIBOR_6M	0.7249	0.8149	-			
SAIBOR_12M	0.7201	0.7867	0.9172	-		
USD_SAR	-0.0185	-0.0258	-0.0290	-0.0291	-	
SABI	-0.0564	-0.0418	-0.0337	-0.0576	0.0085	-

Note: SAIBOR_1M = Saudi Arabia Interbank Offred Rate for 1 month; SAIBOR_3M = Saudi Arabia Interbank Rate for 3 months; SAIBOR_6M = Saudi Arabia Interbank Rate for 6 months; SAIBOR_12M = Saudi Arabia Interbank Rate for 12 months; USA/SAR = Saudi Arabia Exchange rate in USD; SABI = Saudi Arabia Bank Index price.

4.2 Unit root test analysis

The ADF technique is an econometric estimation process that determines whether the dataset is stationary or non-stationary. In particular, it is applied in conjunction with econometric models for time-series investigations. The null hypothesis describes unit root presence or nonstationarity among the variables, and the alternative hypothesis confirms stationarity among the variables. If the p-value is less than the 5% significance level, it rejects the null hypothesis and indicates that the variables are stationary. Table 3 shows the unit root test results, which show that all variables are stationary at the first difference because they meet the criteria of p-value less than the 5% significance leve.

Table 3: Unit root test

Variables	Level		First difference	
	t-value	p-value	t-value	p-value
SAIBOR_1M	0.3579	0.9811	-10.4297	0.0000
SAIBOR_3M	0.1922	0.9721	-7.4773	0.0000
SAIBOR_6M	0.0767	0.9639	-7.3151	0.0000
SAIBOR_12M	-0.0242	0.9552	-6.9306	0.0000
USD_SAR	-2.2852	0.1770	-22.8840	0.0000
SABI	-0.6776	0.8503	-38.0725	0.0000

Note: SAIBOR_1M = Saudi Arabia Interbank Offred Rate for 1 month; SAIBOR_3M = Saudi Arabia Interbank Rate for 3 months; SAIBOR_6M = Saudi Arabia Interbank Rate for 6 months; SAIBOR_12M = Saudi Arabia Interbank Rate for 12 months; USA/SAR = Saudi Arabia Exchange rate in USD; SABI = Saudi Arabia Bank Index price.

4.3 Long term estimation

Given that not all variables are integrated of order I(0) at level; however, all variables are integrated at I(1) at the first difference, we use a co-integration approach for the long-term estimation. Table 4 presents the results of the long-term estimation. The trace and maximum eigenvalue estimations provide the long-term relationship among the variables over the periods since the p-value captures a positive and significant value at the 5% significance level.

Table 4: Long term estimation (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.031455	154.6691	95.75366	0.0000
At most 1 *	0.024924	99.12240	69.81889	0.0000
At most 2 *	0.015542	55.25492	47.85613	0.0086
At most 3	0.008487	28.03123	29.79707	0.0788
At most 4	0.006006	13.21863	15.49471	0.1070
At most 5	0.001581	2.749215	3.841466	0.0973

** denotes rejection of the hypothesis at the 0.05 level,*
** denotes rejection of the hypothesis at the 0.05 level*
***MacKinnon-Haug-Michelis (1999) p-values*

Long term estimation (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.031455	55.54675	40.07757	0.0004
At most 1 *	0.024924	43.86748	33.87687	0.0023
At most 2	0.015542	27.22369	27.58434	0.0555
At most 3	0.008487	14.81260	21.13162	0.3022
At most 4	0.006006	10.46941	14.26460	0.1829
At most 5	0.001581	2.749215	3.841466	0.0973

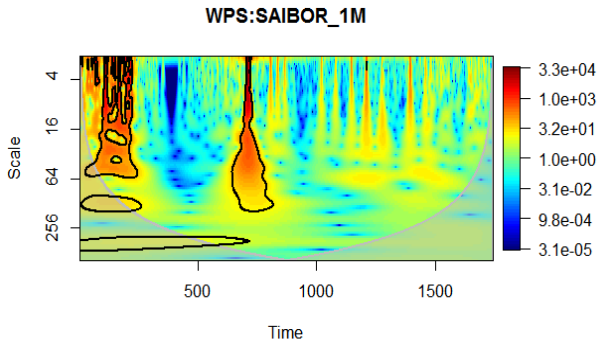
Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
** denotes rejection of the hypothesis at the 0.05 level*
***MacKinnon-Haug-Michelis (1999) p-values*

Moreover, the short-term estimation from the ECM model provides a negative coefficient value, which indicates a short-term relationship among the variables (see appendix-1). However, the relationship varies over the long run among variables. For example, the 3 months, 12 months interest rate and foreign exchange rates have a positive impact, while 6 month interest rate and bank stock returns suggest a negative impact on 1 month interest rate variables (see Appendix-1).

4.4 Wavelet power spectrum (WPS)

We also used the WPS approach, which is popular for measuring the variance of a single variable. It provides image-based results by considering the characteristics of time and frequency domains. Figure 2 presents the results of the wavelet-based variance, where the vertical axis represents time and the horizontal axis represents the frequency domain features. The WPS results are represented by different color codes. For example, the red region represents high variance, the yellow region represents medium variance, and the blue region represents low variance. The results show that the interbank offered rate exhibits high variance during the pandemic and comparatively low variance during the Ukraine-Russia conflict. These findings are consistent with those of previous studies (Batten et al., 2023; Karamti & Jeribi, 2023;

Taera et al., 2023; Tetteh & Ntsiful, 2023). However, the Riyal exchange rate in USD and the return on the bank index showed low variance during the COVID-19 pandemic. During the pandemic, the supply chain was restricted, and normal business operations were suspended (Samadi et al., 2021). Therefore, exchange rate fluctuations were stable during the pandemic. On the other hand, banks' interest rates fluctuated due to the adjustment of the government's monetary policy (Gholami & Abdul-Rahman, 2022).



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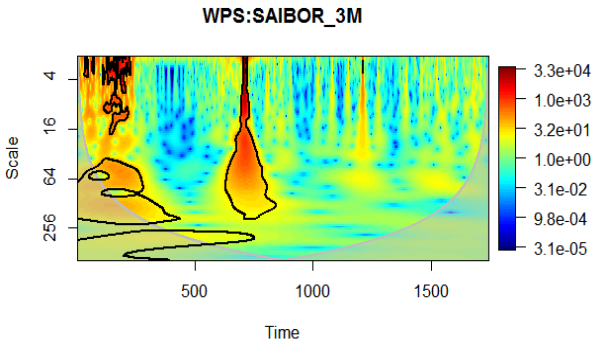

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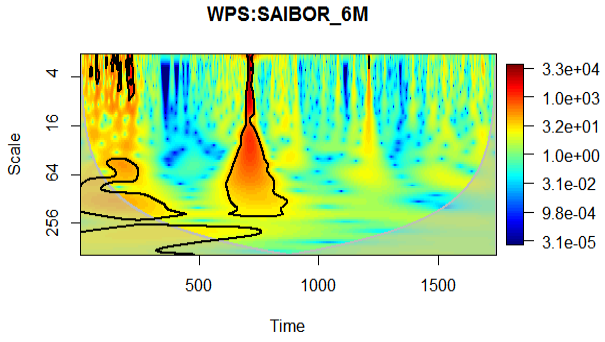

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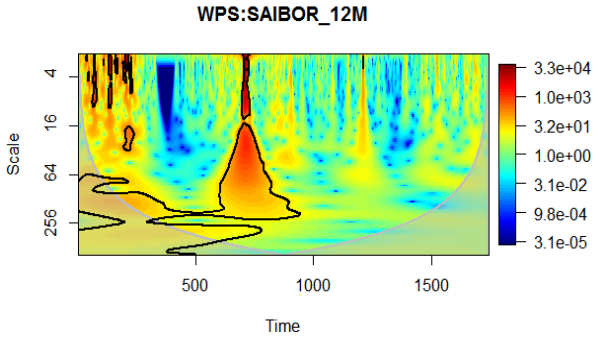
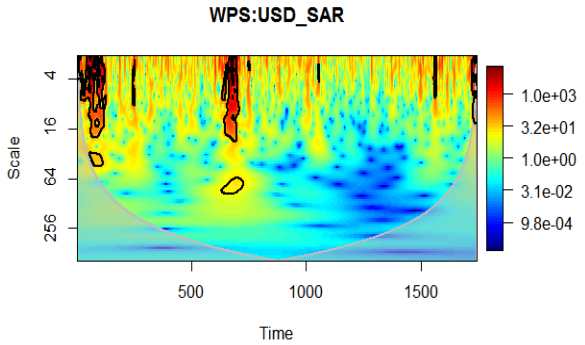
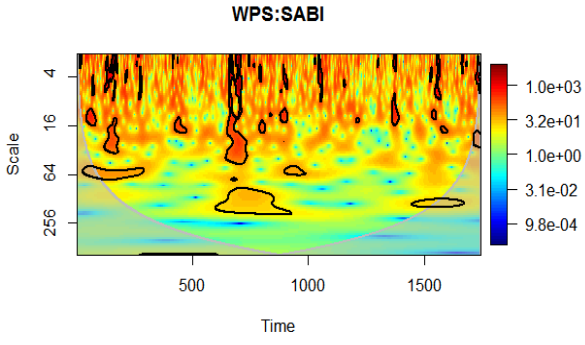


2018/500 2020/1000 2022/1500



2018/500 2020/1000 2022/1500



2018/500 2020/1000 2022/1500

Fig. 2: Wavelet power spectrum results for the *Saudi Arabia Interbank offred Rate for 1, 3, 6, and 12 months, Saudi Arabia Riyal Exchange rate in USD, and Bank Index return.*

Note: SAIBOR_1M = Saudi Arabia Interbank Offred Rate for 1 month; SAIBOR_3M = Saudi Arabia Interbank Rate for 3 months; SAIBOR_6M = Saudi Arabia Interbank Rate for 6 months; SAIBOR_12M = Saudi Arabia Interbank Rate for 12 months; USA/SAR = Saudi Arabia Exchange rate in USD; SABI = Saudi Arabia Bank Index price.

4.5 Wavelet coherence transformation (WCT)

We also investigated the dynamic relationship between the interbank interest rate, foreign exchange (USD/Saudi Riyal exchange rate), and bank index returns during the study period. Figure 3 presents the results of the wavelet coherence between the interest rate and the bank index return. The results show that the interest rate and return on the bank index are weakly correlated in the short holding period at the 4–16 band scales or frequencies. However, the interbank interest rate is strongly correlated with the bank index return in the long run at the 64–256 band scale. A positive co-movement was observed in the years 2018–2020. This trend continues until the COVID-19 period for each 1–12M interbank offered rates. However, compared to the other yields, the 1M interbank offered rate has a stronger long-term influence on the yield of the bank index (e.g., 64–256 band spaces). This result could justify the status of Saudi Arabian commercial banks' mortgage loans. The assets, loans, and deposits of Saudi Arabian commercial banks have grown significantly in recent years (Alsharif, 2020, 2021). Therefore, banking index returns and banks' interest rates are positively correlated in the long run. Interestingly, the impact or correlation between the interbank interest rate and the bank index return during the Ukraine-Russia conflict is comparatively lower in the long run, with 16–64 band spaces. Furthermore, Figure 3 shows that a lead-lag relationship exists between the interbank interest rate and the bank index return. The results reveal that the second variable (e.g., the bank index yield) takes a leading position during the holding period 2018–2020, as the left arrow points downwards (↘) and the right arrow points upwards.

Figure 4 exhibits the results of the wavelet coherence between the interbank interest rate and exchange rate of Saudi Arabia. The results reveal that the interest rate and exchange rate are positively correlated and highly volatile during the long holding period (e.g., 2018–2020). This trend also continues until the COVID-19 period for each 1–12M interbank rate. Similarly, the 1M interbank offered rate has a stronger long-term influence on the yield of the bank index (e.g., 64–256 band spaces). Moreover, the lead-lag analysis exhibits that the exchange rate takes a leading position in this context, as the left arrow points downwards. This could be due to the characteristics of fluctuation in the properties of the time-frequency domain, increasing uncertainty and geopolitical risk, and the impact of monetary policy (Raza Rabbani et al., 2023).

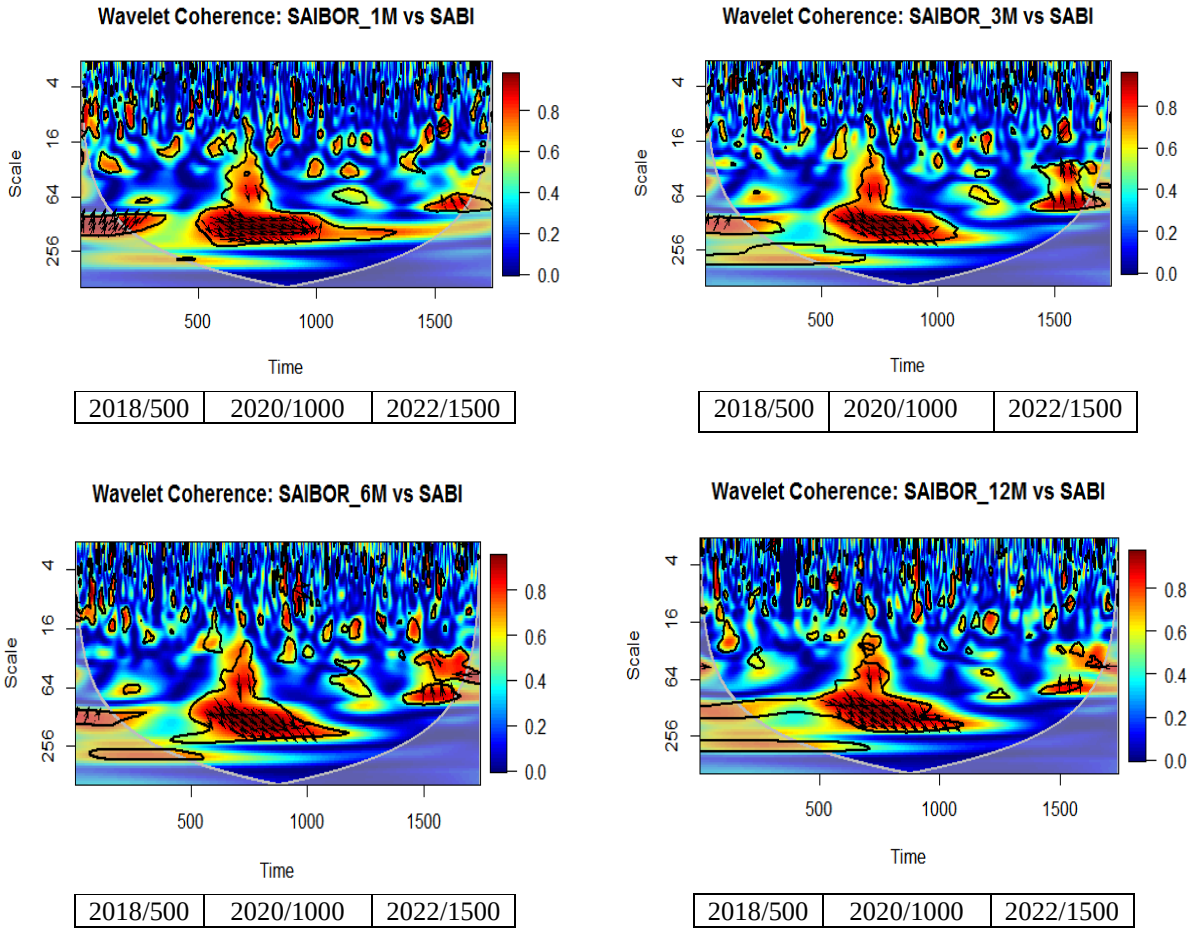


Fig. 3: Wavelet coherence results for one month vs. bank index return, *interbank offered rate for 1 month vs bank index return, interbank offered rate for three months vs. bank index return, interbank offered interest rate for six months vs. bank index return, and interbank offered interest rate for 12 months vs. bank index return.*

Note: SAIBOR_1M = Saudi Arabia Interbank Offred Rate for 1 month; SAIBOR_3M = Saudi Arabia Interbank Rate for 3 months; SAIBOR_6M = Saudi Arabia Interbank Rate for 6 months; SAIBOR_12M = Saudi Arabia Interbank Rate for 12 months; USA/SAR = Saudi Arabia Exchange rate in USD; SABI = Saudi Arabia Bank Index price.

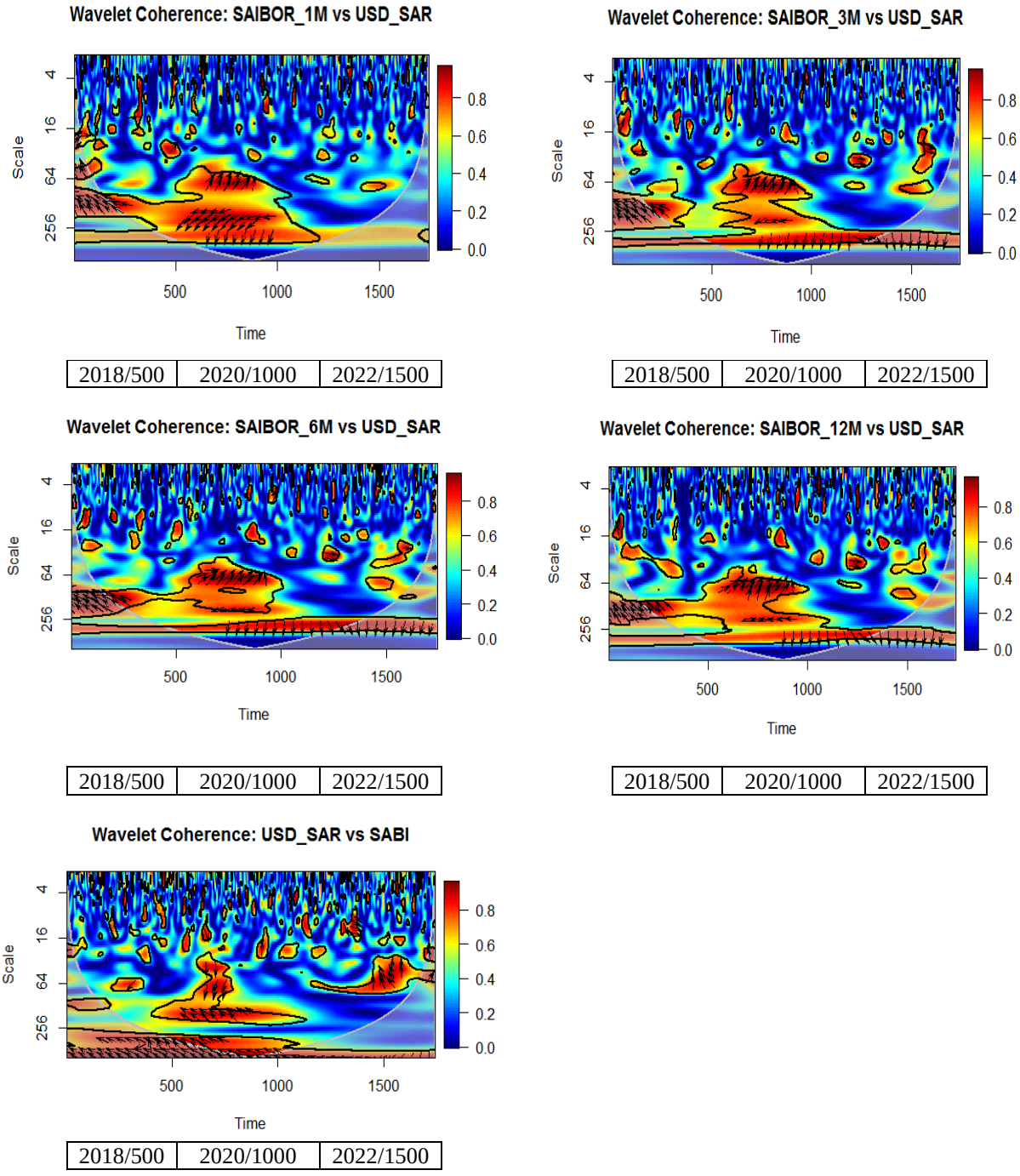


Fig. 4: Wavelet coherence results for the *Saudi Arabia Interbank Offred Rate for 1 month vs. Riyal exchange rate, interbank offered rate for 3 months vs. Riyal exchange rate, interbank offered interest rate for 6 months vs. Riyal exchange rate, interbank offered interest rate for 12 months vs. Riyal exchange rate, and* the *Saudi Arabia Riyal exchange rate vs. bank index return.*

Note: SAIBOR_1M = Saudi Arabia Interbank Offred Rate for 1 month; SAIBOR_3M = Saudi Arabia Interbank Rate for 3 months; SAIBOR_6M = Saudi Arabia Interbank Rate for 6 months; SAIBOR_12M = Saudi Arabia Interbank Rate for 12 months; USA/SAR = Saudi Arabia Exchange rate in USD; SABI = Saudi Arabia Bank Index price.

5. Conclusion

This study analyzes the relationship between interest rates, exchange rates, and bank stock returns in Saudi Arabia by using wavelet analysis. The results show a significant relationship between the variables in the short and long run, considering the characteristics of the time domain. However, the dynamic relationship varies in both time- and frequency-domain properties. In particular, it can be seen that the interbank offered rate has a high variance during the COVID-19 pandemic and a comparatively low variance during the Ukraine-Russia conflict. However, the exchange rate of the riyal against the USD and the return of the bank index showed low variance during the COVID-19 pandemic. Furthermore, the results suggest that the interest and exchange rates are positively correlated and exhibit high volatility in the long holding period (e.g., 2018–2020), in which the bank index return took a leading position during the COVID-19 pandemic.

This study identified certain risks and opportunities associated with macroeconomic fluctuations in Saudi Arabia's banking system. Using these insights, policymakers, regulators, and banking executives can make informed decisions regarding their banking operations in the country, based on the study's analysis of risks and opportunities. The findings of the study may be used for assessing Saudi banks' vulnerability to macroeconomic shocks and adjusting their risk management strategies accordingly. Moreover, the study could also inform strategic decision-making by banking executives regarding their operations in Saudi Arabia's distinct dual banking system and economy. This could include decisions related to expanding their services, entering new markets, or diversifying their portfolios. Stakeholders in the Saudi banking industry can benefit from the insights provided by the study to address the challenges and opportunities presented by the dynamic economic environment of the country.

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Appendix 1: Short term estimation (ECM model)

SAIBOR_1M	SAIBOR_3M	SAIBOR_6M	SAIBOR_12M	USD_SAR	SABI
1.000000	-2.885364	4.403472	-2.435583	-25.82331	8.81E-06
	(0.59561)	(1.27998)	(0.74733)	(18.5760)	(1.3E-05)
Adjustment coefficients (standard error in parentheses)					
D(SAIBOR_1M)	-0.004181				
	(0.00346)				
D(SAIBOR_3M)	0.006696				
	(0.00286)				
D(SAIBOR_6M)	-0.007518				
	(0.00196)				
D(SAIBOR_12M)	-0.003463				
	(0.00210)				
D(USD_SAR)	-2.57E-05				
	(6.3E-05)				
D(SABI)	13.13337				
	(10.6716)				