INDUS JOURNAL OF SOCIAL SCIENCES

https://induspublishers.com/IJSS

Volume 2, Issue 2 (2024)

Original Article

Re-Visiting the Co-movement between FinTech, Economic Policy Uncertainty, Governance Quality and Bank Variability in Pakistan: A Wavelet Coherence Approach

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ARTICLE INFO

Key Words:

FinTech, Economic Policy Uncertainty, Governance quality, Bank Variability, ARDL, CWT

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ABSTRACT

The recent literature about FinTech services in Pakistani commercial banks has grabbed much attention as these services have increased rapidly in the last few decades. This paper examines the co-movement between FinTech, economic policy uncertainty, bank- variability, and governance quality. The data was obtained from 2014-2020 on a monthly frequency. To address the relationship and co-movement, we have applied more advanced and sophisticated econometric models, autoregressive distributed lag model (ARDL), and continuous wavelet (CTW) to investigate the relationship between the variables. These approaches provide flexibility of assumptions for time-series data and provide robust results. The results indicate a short and long-run symmetric relationship with a significant co-movement between the variables.

Introduction

The driving force behind the advancement of financial technologies in banks is globalization. (Achieng et al., 2015) and the use of technology in financial institutions is termed "FinTech". FinTech services are an important part of financial inclusion and economic growth. FinTech services have a long history with the start of punch machines in banks before World War I, automated teller machines (ATMs), in Ohio (1960), mobile payment systems, transfer of funds, cheque management, bill payment, and online & digital banking (Charfeddine et al., 2024). Over the past two decades, FinTech services have completely transformed the traditional banking system (Tang et al., 2024) by adding peer-to-peer (P2P), business-to-customer (B2C), and customer-to-customer (C2C) banking. These business models boost the banking sector and

provide an easy approach to banks and customers. FinTech services are one of the relatively new trends in the banking sector and there is a lot of scope for further study in this area. Developed nations are typically at the forefront of innovation and uptake in digital banking. Here's an overview of several important features. Developed countries generally exhibit a significant amount of Internet and smartphone adoption, which fosters a favorable environment for the growth of digital banking services. The conventional banking models are being disrupted by the rise of FinTech startups and neobanks. These companies that prioritize digitalization frequently provide more customer-focused strategies, reduced costs, and specialized financial services. After getting much attention in developed countries, FinTech services penetrate in banks of developing countries. Pakistan, among these developing countries, is still enhancing the Fintech services in commercial banks to facilitate customers.

FinTech services in Pakistani banks started in 1990, installing the first ATM, while eight Pakistani banks went online in 2000 (Mehmood et al., 2014). The State Bank of Pakistan declares that e-banking transactions increased by 16% in value and 13% in volume during the first quarter of Fiscal Year 2021–2022, continuing the rapid expansion of the nation's payment ecosystem[i]. During recent years a rapid growth of FinTech services in Pakistani commercial banks has been observed due to the growing need for convenient financial solutions and technological improvements. Through online and mobile banking systems, Pakistan's traditional banks, like Habib Bank Ltd.,[ii] United Bank Ltd.,[iii] and Muslim commercial banks[iv] have been improving FinTech services. These banks serve a wide range of customers and also offer creative solutions, such as mobile wallets and payment systems, through firms like RAAST[v], Easypaisa, JazzCash, and Upaisa. To regulate these services, the State Bank of Pakistan (SBP) took the initiative to create policies to encourage the expansion of FinTech services and digital banking[vi]. A safe and competitive digital financial ecosystem is being promoted by projects like the Digital Payment Gateway and the new rules for Electronic Money Institutions (EMIs). Despite advancements, Pakistan's FinTech services in banks face obstacles[vii]. The effectiveness and reach of digital banking services can be impacted by problems like low internet penetration in rural areas, cybersecurity issues, and the requirement for increased financial awareness among customers (Santos et al., 2021).

Thus, the growing use of smartphones and the requirement for cashless transactions have led to the digital banking industry growing fast in Pakistan. The commercial banks used specific platforms for Digital Banking named “U Bank” which provides some digital services, such as online account registration, fund transfers, and bill paying[viii]. Moreover, by using the app, Mobilink Microfinance Bank (JazzCash) offers mobile banking services such as money transfers, payments, and account management (Cheng & Masron, 2023). This is also one of Pakistan's top mobile wallet services that makes online shopping, money transfers, and bill payments easier. Initially, stable online banking services, such as account administration and investing choices, were offered by Standard Chartered Bank in Pakistan[ix]. Thus, Pakistan's Real-time interbank payments are made easier via the Pakistan Real-Time Interbank Settlement Mechanism (PRISM) allows electronic payments and transfers between banks through the payment system and electronic funds transfer (PSEFT) Pakistan Electronic Funds Transfer (PEFT) system[x]. Moreover, National Institutional Facilitation Technologies (NIFT) has provided a platform that works as an electronic clearing house for e-cheques, electronic-Image Clearing (IBCS), and the infrastructure of the interbank payment system for overseas Pakistanis’[xi]. Pakistani commercial banks are rapidly absorbing FinTech development that alters the banking sector as open banking,

mobile & internet banking (Afshan et al., 2018), cheque-less banking, branchless banking, and artificial intelligence. In the upcoming years, voice banking, augmented reality, cybersecurity, and personalized banking will all have a significant impact on the banking sector[xii].

Based on the evidence from developed countries, banking services including FinTech are sensitive to economic policy uncertainty (EPU) (Gissler et al., 2016), governance quality (GQ), and bank variability (Correa, & Goldberg, 2022). The term "economic policy" includes a vast range of activities that influence the economy to accomplish desired goals including growth, stability, and equity (Wallace et al., 2020). Frequent occurrences of unforeseen events over the past few decades with contagion effects, such as the Global Financial Crisis (GFC) of 2007–2008, the trade conflict between the United States and China, the COVID-19 pandemic (Berger, & Kunt, 2021), and the ongoing conflict in Ukraine (Khurshid et al., 2024) and Gaza[xiii](Batten et al., 2023). These events shook the whole economic and financial system (Wang et al., 2024) and surged policy uncertainty(Ji, D et al., 2023 & Ameer, W., et al., 2024). This caused a significant contribution to high uncertainty in the global economy. This economic uncertainty compels nations to devise certain policies to mitigate the negative effects and promote economic recovery (Yujia et al., 2024). The banks are susceptible to failure in times of high economic uncertainty and interdependence of banks can spread shocks and lead to overall volatility in the global financial system like GFC (Batten et al., 2023). Economic policymaking is globally interconnected and foreign EPUs always interact with local EPUs especially in the case of the banking sector due to high integration in the global financial sector (Hong et al., 2024). Thus, economic policy uncertainty deteriorates FinTech services in banks and hinders online and mobile banking around the world (Olalere & Petersen, 2024). Like other services like loan loss provisions (Ozili 2022), stability (Fukuyama, & Tan, 2022), performance (Hamza et al., 2022), and profitability (Sing et al., 2021).

Other than economic policy uncertainty, bank variability also causes to decrease in banks' Fintech services (Trinh & Tran, 2023). The stock market is a hub of the financial sector while banks being institutional investors play a vital role in enhancing the banking business (Konou, 2023). The investments appear to be safer in the stock markets of industrialized countries, but because of an inadequate financial and economic infrastructure, emerging markets are more vulnerable to shocks (Marcelin et al., 2022). The price of banking stocks is linearly correlated to the general level of market risk; hence, the bank-variability has an impact on banking services such as FinTech (Rafiq et al., 2019). Because of the increasingly interwoven financial markets brought about by globalization, stock market variability is linked to changes in the global financial market (Zhang & Broadstock, 2020). Bank variability is measured by the standard deviation of stock returns and has been observed to spread from developed to emerging economies. However, with inadequate infrastructure, emerging country stock markets are less equipped to withstand variability (Abbas et al., 2020).

Elevated bank variability has a significant effect on banking services by decreasing loss absorption and reducing profit sharing to customers (Qamruzzaman, 2023). Sometimes, banks must recoup their losses in the stock market by raising interest rates on loans, credit cards, online transactions, mobile banking, and other FinTech services. In this sense, fluctuations in the stock market led to a decline in bank FinTech services as clients are burdened by a rapid increase in FinTech service rates during stock market variability (Ekeocha et al., 2023). Furthermore, the Pakistan Stock Exchange is exposing inflation and interest rates (Alim et al., 2021) due to changes in IMF programs, economic instability in internal governance (Altaf et al., 2022),

monetary policy, and macroeconomic factors (Mohsin et al., 2022), and shortage of US dollars (Srinivas, 2020) being driving forces of increased variability. State Bank of Pakistan examines the risks for commercial banks and reveals that bank variability influences FinTech services[xiv]. The investors are likely to relocate investments in the commodity market rather than buy bank shares[xv].

Along with economic policy uncertainty and bank variability, governance quality (GQ) such as government effectiveness (Mizrahi et al., 2021) and regulatory quality affect FinTech services in developed countries. Strong governance quality is positively associated with bank stability, profitability, and e-services that absorb certain volatilities by winning investors' trust (Pratama & Hermawan 2023). Similarly, the conceptual foundation of the relationship between financial inclusion programs[xvi] and governance indicators show the significance of governance quality for FinTech like other banking services. Since financial growth includes financial access, governance quality, and financial inclusion are also entwined with economic growth (Sayılır et al., 2018; Park and Mercado, 2018). Effiong (2016) and Alarifi & Husain (2023) discuss the connection between financial development and economic expansion, basing the conclusions on the bank's standing[xvii] and the quality of its services (Ho & Michaely,1988).

Commercial banks prefer to voluntarily divulge less information when they operate in countries that uphold the rule of law, high-quality regulations, and effective governments (Lambert & Volpin, (2018; Chaudhry et al., 2022; Chen & Shen 2023). There is a relationship between banking services, economic growth, and inflation, moreover, the banks' internal factors like size, loans, loan to total asset ratio, and growth also affect services. While examining the relationship, this paper controls these variables to get accurate results. However, other than risks, uncertainties, and challenges, certain contributing factors promote FinTech growth in Pakistan. The growth of FinTech services is considerably affected and is associated with certain factors like the other bank services which are getting more important as the advancement of FinTech services in Pakistani commercial banks. State Bank of Pakistan has started many schemes and attract Pakistani as well as overseas customers who are more concerned with contributing factors of FinTech services in Pakistan. Concerning bank deposits, investments, and loans, customers need to understand the policy uncertainty, governance quality, and bank variability in Pakistan.

Based on the arguments, as per our best knowledge, there is no significant research in Pakistan that addresses the factors that co-move with FinTech services in commercial banks, while having a huge portfolio of bank FinTech services. To fill this gap, we examine the short & long-run association and co-movement between FinTech, economic policy uncertainty, governance quality, and bank viability in Pakistani commercial banks. This study contributes by presenting the combined effect of these three factors on FinTech while controlling macroeconomic and bank-specific factors[xviii], which have not been examined previously, and by pointing out that self-efficacy is not very significant in the Pakistani context. To address our research question, we apply the autoregressive distributed lag (ARDL) model by Pesaran et al., (2001) and continuous wavelet Transforms (CWT). In econometrics, the Autoregressive Distributed Lag (ARDL) model is a statistical method for examining the short- and long-term relationships between variables, when working with time series data that could contain a combination of stationary and non-stationary variables, it is also helpful in different orders of integration.

The ARDL model is versatile for various types of data since it can be used regardless of whether the underlying variables are I(0), I(1), or a combination of both. Another effective technique for concurrently analyzing the relationships between two-time series in the time and frequency domains is the Continuous Wavelet Transforms (CWT) approach initiated by Grossmann & Morlet (1984). It is a progression of the continuous wavelet transform (CWT), It divides a time series into time-frequency space and reveals localized frequency changes over time. In particular, wavelet coherence quantifies the local correlation between two-time series as a function of frequency and time (Jeris & Nath (2021).

This paper is divided into four sections: section 2, Review of Literature, section 3, Data and Methodology, section 4, Results and Interpretation, and section 5, Conclusion and Recommendations.

Literature Review

Based on the Schumpeterian Theory (Schumpeter, 1939), which was published in his book "Theory of Innovation (1943)," King and Levine (1993) investigated in a groundbreaking work that finance is necessary for both innovation and economic growth and development. King and Levine (1993) identified the pathways of financial intermediaries that contribute to capital allocation and economic innovation by saving money for investments (Zhao, J et al., 2023 & Song, M et al., 2024). A part from Schumpeter's "finance–innovation–economic growth/development" nexus technological advancements and benefit finance. This concept is further explained as “Financial Technology” (FinTech) in the modern world and has grown much due to digitalization in developed and developing countries (Anyfantaki, 2016). However, like other banking services, certain factors play an important role in the success or deterioration of banks’ FinTech services.

Between 2007-2016, regression analysis is performed on 55,200 firm-level observations from six Asian economies using the two-step GMM (generalized method of moments) approach. According to the statistical findings, EPU has a favorable association with equity financing but a negative relationship with debt financing (Tabash et al., 2022). Additionally, between 2011-2018, Bangladesh's economic growth was positively correlated with FinTech services (Banna, 2020). Therefore, economic growth has been used as a control variable while analyzing the association between EPU and FinTech. Syed (2023) investigates and finds an increase in economic policy uncertainty decreases the stability of the Indian banking industry from 2000 to 2022. Wen et al. (2022) attempt to examine the symmetric and asymmetric relationship between economic policy uncertainty (EPU) on economic growth in Pakistan by controlling bank-specific variables and applying the linear and nonlinear autoregressive distributive lag (ARDL & NARDL) technique and find that EPU is negatively associated with banking services and economic growth.

Unlike previous research, the goal is to calculate the impact of uncertainty using Baker et al., (2016)'s created EPU index[xix]. The results of the nonlinear (NARDL) model indicate that positive shocks have a larger magnitude than negative shocks and that a high EPU has an impact on short-term economic growth. The literature also discusses that by using an imbalanced data panel constructed on a sample of 1060 listed commercial banks from 46 developed and developing countries between 2010-2017. The countries with weak governance quality (GQ) influence FinTech and, consequently, economic growth. In contrast, there is no similar evidence

in countries that have strong GQ (Úbeda et al., 2022). These pieces of evidence reveal a negative relationship between FinTech and economic policy uncertainty while controlling economic growth, macroeconomics, and banks' internal factors.

Anastasiou et al. (2019) examined in Greece, from 1996 to 2016, show the noteworthy impacts on non-performing loans (NPLs) of a recently developed variable called "Governance index," the latter of which is derived from a principal component of the Worldwide Governance Indicators (2022) for analysis (WGI)., the research finds certain macroeconomic factors that affect the relationship that is needed to control like GDP, economic growth (Umar & Sun, 2018), inflation (Rachid 2019), unemployment and exchange rate (Byükoğlu et al., 2021). This study uses data from 80 banks in four ASEAN nations from 2006 to 2019 to investigate the link between market concentration, governance quality, and a bank's financial stability. The study produces some fascinating results. It suggests a favorable correlation between governance quality, proxy by WGI, and bank stability by employing the System Generalized Method of Moments (SGMM). Furthermore, the study controls bank size, liabilities, balance sheet ratios, inflation, and economic growth to find more robust results. To be more specific, government effectiveness reduces the default ratio of bank loans and helps to improve FinTech service quality by providing more security to borrowers and depositors (Nguyen,2023). Similarly, Park and Mercado (2015) discuss financial inclusion in 37 developing Asian economies between 2004 and 2012. Ghazal & Zulkhibri (2017) use panel data analysis from Muslim and developing nations to examine the relationships between financial inclusion, institutions, and governance quality using data on the characteristics of over 100,000 individuals from the Global Findex database[xx]. While, during 2011 and 2013, Africa, South Asia, East Asia and the Pacific, Eastern Europe, and Central Asia were examined for FinTech and banks' relationship. The findings indicate that FinTech may be accelerated by increasing the number of bank accounts and savings in formal financial institutions, while strong governance quality is defined as the eradication of corruption, the improvement of a clear legal framework and the rule of law, and effective administration.

Ajide (2017) examines the effects of governance and institutional infrastructure on financial inclusion between 2004 and 2010 and regarding 49 African nations, Bakari (2021) found extremely close findings during 1960-2018 by applying Panel DOLS and FMOLS Estimates; Panel ARDL Model; Panel VECM; Pooled OLS, Fixed Effect Model, Random Effect Model, and Hausman Test; Panel Toda-Yamamoto Causality Test; Panel Pairwise Granger Causality Tests; and Panel GMM Model. the results explored a significant relationship between innovation and economic growth and a relationship between financial inclusion and governance quality (Abaidoo, & Agyapong, 2023). Therefore, control inflation, interest rates, GDP, and economic growth (Eldomiaty, 2020) from Thirteen listed banks on the Pakistan Stock Exchange are the sample used in this research. On the contrary, from January 2007 to December 2018, a negative correlation exists between Pakistani banking services and market volatility (Rafiq et al, 2019). The above discussion reveals that EPU, GQ, and bank variability are specifically considered and examined to co-move with Fintech and are associated during the short- and long-run, while the data from Pakistani commercial banks are found to be nonlinear.

Data and Methodology

Data

The data has been obtained from 2014 -2020 from 19 commercial banks on monthly frequency, FinTech proxies from the World Development Indicator and International Monetary Fund (IMF), and are aggregated by applying principal component analysis (PCA) that computes weights, following the methodology of Park and Mercado (2018). Additionally, we employ Pakistani economic policy uncertainty measures, constructed by Choudhary et al. (2020) from the State Bank of Pakistan followed by Baker et al. (2016). The index was created using data from two newspapers published between 2010 and 2020[xxi]. Governance quality data has been obtained from World Governance Indicators. The data of bank variability is calculated by the author[xxii]. The period consists of 7 years (2014-2020) on monthly frequency.

Frequency Conversion Methods

Frequency conversion of the data is needed as the variables have different frequencies such as governance quality (GQ) and FinTech data is available at an annual frequency, EPU on monthly, and bank variability data is also available on a monthly frequency. This study has confronted the hitch of converting low-frequency data (annual) to high-frequency data (monthly data).To address the problem of low-frequency series, we have used a quadratic equation of the observations to exhibit the time series at the monthly frequency by splitting the data following the methodology (Yeo et al. 2019). This helps to use all available data at the same frequency (monthly) with 84 observations and present the observations by summarizing the monthly patterns of the data.

Methodology

To address our research question, we have applied unit root tests to examine stationarity in the time series data, correlation analysis to continue for testing co-movement, autoregression distributed lag model (ARDL) to find the relationship with lag values of FinTech, and continuous wavelet approach (CWT) to test co-movement.

Testing Unit root test

We apply the Augmented Dickey-Fuller (ADF) test to ascertain whether the series has a unit root. A statistical test called the Dickey-Fuller test was developed in 1979 by David Dickey and Wayne Fuller to test if a time series is stationary or has a unit root, which would indicate non-stationarity. Because the characteristics of the time series data can greatly affect the outcomes and interpretations, this test is essential in time series analysis, particularly when working with econometric models.

Correlation Analysis

A statistical technique for determining the direction and magnitude of a relationship between two variables is correlation analysis. It computes the relationship between changes in one variable and changes in another. The correlation coefficient (r), which serves as the primary indicator in correlation analysis, is the representation of the correlation coefficient. Where r has a value in the range of -1 and +1. A perfect positive correlation (+1), denotes a rise in one variable that reflects the rate of rise in the other. A perfect negative correlation (as in, one variable increases as the other does) is a value of -1. 0: The variables do not correlate or have a straight-line relationship. The Pearson Correlation Coefficient quantifies the linear relationship between two continuous variables. Pearson's correlation assumes that the variables have a linear association (Pearson, 1897).

Autoregressive Distributed Lag model (ARDL) and Wavelet Coherence

Before using Wavelet Coherence in a time series analysis, it is helpful to use an ARDL (Autoregressive Distributed Lag) model by Pesaran et al., (2001). The long-term equilibrium relationship between the variables and the short-term dynamics are ascertained with the use of the ARDL model. This makes it easier to comprehend how the variables are correlated over various periods before doing a thorough analysis of the time-frequency domain. Moreover, the stability of a relationship over the long run is impacted by short-term alterations by employing ARDL to assess these associations. Additionally, ARDL handles different integration orders I(0) and I(1) without the need for variance, preserving long-term information. It makes it possible to test cointegration, or long-run equilibrium relationships, between variables. According to recent research, non-stationary data could result in misleading coherence, making it tricky to assess wavelet coherence (Alsamara, 2022).

Thus, ARDL is a simpler method for determining and approximating relationships over various time lags by making it possible to have a basic idea of which lags are important and how different factors interact over time. This initial stage can assist in narrowing the focus while examining Wavelet Coherence's more intricate, multi-scale interactions. Moreover, the dynamics of the relationship between variables can be understood by using the basis that ARDL offers. The choice of frequency bands and periods for Wavelet Coherence research can be influenced by the insights gained from ARDL. Understanding the important lags and dynamics facilitates the interpretation of which frequencies and time periods would be most relevant for further investigation. One way to determine whether a strong relationship is proposed by wavelet coherence The ARDL model holds accurate across several time and frequency domains. However, if the model shows no discernible association, Wavelet Coherence might be able to highlight time-localized or frequency-specific correlations that ARDL missed (Maghyereh, & Abdoh, 2020).

ARDL Model

When working with heterogeneous order of integration, limited sample sizes, and the need to capture both long- and short-term correlations between variables, the ARDL model proves to be a versatile and efficient tool for time series analysis.

$$\Delta FinTech_t = \alpha + {}_1FinTech_{t-i+2}EPU_{t-i\ 3}BV_{t-I\ 4}GQ_{t-i+} \gamma_1 FinTech_{t-i} + \gamma_2 EPU_{t-i} + \gamma_3 BV_{t-i} + \gamma_4 GQ_{t-i} + \epsilon_t \quad (1)$$

Continuous Wavelet Transform

Wavelet analysis originated from several schools of thought that were first isolated before coming together to form Haar (1910) current areas of research. Alfred Haar (1910) wrote the first piece of work on wavelet analysis at the turn of the century and discovered an orthogonal set of functions on what is now regarded as the base for the wavelet family and given the Haar wavelet's name in his honor. More significant advancements in the field of wavelet analysis have been accomplished since the publication of Haar's work. Among the wavelet analysis, continuous wavelet transformation (CWT) was first discovered by Zweig in 1975 and discussed by Parker in 1987, and it was further developed by Goupillaud, Grossmann, and Morlet in 1982. Other notable contributions include Daubechies' construction of orthogonal wavelets with

compact support in 1988, Mallat introduce a multiresolution framework in 1989, Delprat's time-frequency interpretation of CWT in 1991[xxiii], and many others.

Applications of wavelet analysis have lately expanded to a wide range of fields, with the primary focus of this study being economics and finance (Jeris & Nath, 2021). During the previous few decades, with the rise of big data, particularly in finance research, where numerous financial factors, including stock prices, can now be recorded minute by minute or even second by second. Financial data sets grow huge, exhibiting great levels of complexity, unpredictability, and volume (Bales, 2022). This growing sophistication needs data processing technologies now more than ever. Mathematical theories and applications are highly desired by scholars and experts in the sector as they enable them to make sense of the huge amount of data and utilize it for a better understanding of financial systems or for making informed judgments in general (Xu et al., 2021).

Some classic data analysis techniques, such as time-series analysis, that focus on the time domain, and spectrum analysis, frequency domain, are being reevaluated due to their limits as a result of the advancement of data analysis tools (Mandler & Scharnagl, 2022). The first drawback is that these conventional methods typically necessitate a strong presumption that the data is derived from an underlying process; specifically, the data must be stable and variance does not vary with time or exhibit any trends. For many time series in the financial and economic domains, this is scarcely the case. These series' variance or volatility typically exhibits intricate patterns and trends such as structural breaks, clustering, and extended memory. Another drawback of spectral analysis is that frequency decomposition is only meaningful in situations where market activity is consistent across the course of the analysis. Thus, CWT has the benefit of being able to separate simpler-structured components of extremely complex functions. Then, we can examine each of the smaller components rather than the original function as a complete unit (Kant et al., 2020; Sing et al., 2020; Gupta et al., 2021).

Continuous wavelet analysis can be used to find discontinuities in data since it is adaptable and does not require significant assumptions about the process of generating the data (Kirik, 2023).
These advantages may result in a wide range of uses. Financial and economic time series discontinuities or regime shifts can be found using wavelet analysis. It can also be applied to models that don't make a lot of assumptions about the time series' underlying processes. A discrete wavelet () is analyzed against the time sequence x(t) $\epsilon L^2\mathbb{R}$ to obtain this kind of wavelet transform W(x)(mn), i.e.

$$Wx(mn) = \varphi\ (t\text{-}m/N)\ dt \qquad (2)$$

The capacity to break a time series x(t) $\epsilon L^2\mathbb{R}$ and then seamlessly rebuild it is a crucial feature of the continuous wavelet transform:

$$x(t)= 1/C\ \varphi_{m,n}(t)\ du\ ]\ dn/N^2,\ N>0 \qquad (3)$$

Furthermore, the power of a specific time sequence under observation has been altered by the continuous wavelet.

$$\| x\|^2= 1/C\ \varphi_{m,n}(t)\ du\ ]\ dn/N^2 \qquad (4)$$

In this work, we apply these features to estimate the native relationship length between variables within the defined time frame, or wavelet coherence (Arif & Suleman, 2017). One informative method for examining the time-frequency relationship between two time series is Continuous Wavelet Coherence (CWC). Determining these series' intensity and phase connection across time and at various scales or frequencies is helpful (Crowley & Hallett, 2021).

Results and Discussion

To understand the data characteristics, we apply descriptive statistics. Table 1, represents the sample distribution in the statistical form of FinTech, economic policy uncertainty (EPU), governance quality (GQ), bank-variability, and control variables that include bank-specific control variables (BSC), and macroeconomic control variables i.e., inflation (INF), and economic growth (EG).

Table 1. Descriptive Statistics

In Table 1, the summary statistics shed light on average values, standard deviation, min, max values 50th percentile, skewness, and kurtoses. Berger et al.; (2021) explain that low standard deviation shows less inclusion of systematic risk and vice versa in FinTech services.

Variables	Obs.	Mean	Std. Dev.	Min	Max	p50	Skew.	Kurt.
FinTech	84	-7.83E-08	1.8787	-2.6536	3.4547	-0.0466	0.1982	1.7113
EPU	84	1000.270	429.890	332.100	2548.000	923.300	1.032	4.053
GQ	84	-2.57E	1.233	-4.362	1.514	0.211	-1.630	5.832

		-0.081	2	3	0	1	3	0
BV	84	1.20E-07	2.816	-3.996	16.391	-0.642	2.637	15.161
INF	84	7.907	6.155	0.102	20.704	6.792	0.868	2.713
EG	84	3.820	2.420	-3.037	6.459	4.619	-1.411	3.950

Note: Table 1 consists of the values of mean, standard deviation, minimum, maximum values, median, skewness, and kurtosis.

Economic policy uncertainty in Pakistan contributes more uncertainty to FinTech because the standard deviation is high, far from the mean value. The key influencing variables, economic policy uncertainty, have a high mean and SD values of 100.2270 and 42.9890 resulting in high inclusion of systematic risk due to far away from mean values. FinTech data is skewed on the left side while not mesokurtic, while the economic policy uncertainty is positively skewed and leptokurtic with fat tails risk reveals most of the values lie at tails. On the other hand, the bank variability data has a low average and standard deviation values depict less systemic risk inclusion, positively skewed and mesokurtic and leptokurtic. The data on governance quality has a low standard deviation, is mesokurtic, and is negatively skewed. The control variable bank-specific control variable has a low average value with less stability, while the distribution is negatively skewed and platykurtic with a thin tail, the same as the characteristics of inflation data. While economic growth in Pakistan is revealed to be stable, negatively skewed, and mesokurtic.

Table 2. Unit Root Test

Variables	t-Stats	1% Critical Value	5% Critical Value	10% Critical Value	I(0)/I(I)P Value
FinTech	-6.4610	-4.0800	-3.4680	-3.1610	0.0000

EPU	-5.8040	-4.0770	-3.4670	-3.1600	0.0000
GQ	-3.8460	-4.0800	-3.4680	-3.1610	0.0144
BV	-6.4510	-4.0770	-3.4670	-3.1600	0.0000
INF	-4.1270	-4.0770	-3.4670	-3.1600	0.0057
EG	-6.4040	-4.0800	-3.4680	-3.1610	0.0000

Note: The values reported ADF unit root test of stationarity (Dickey & Fuller 1979), with the null hypothesis that stationarity is present in the series.

Table 2 reveals the results of the Augmented Dickey-Fuller test for stationarity. The variables are stationary at a 5% significance level, based on the data in the table above. The detail of the test finds that economic policy uncertainty and bank variability are stationarity at level, while FinTech, bank-specific control variable, inflation, and economic growth are stationarity at first difference. However, the governance quality data is stationary at 2nd difference (Shrestha, & Bhatta, 2018). To apply the ARDL model of this study, the stationary test is important as the governance quality data denies the basic assumption of the ARDL model, while the model applies to other variables.

Table 3. Correlation Matrix

	FinTech	EPU	BV	GQ	BSC	INF	EG
FinTech	1.0000						
EPU	0.6135* (0.0000)	1.0000					
BV	0.3150*(0.0035)	0.3099*(0.0041)	1.0000				
GQ	-0.6718*(0.0000)	-0.3371*(0.0000)	-0.1183 (0.2840)	1.0000			
BSC	0.9868*(0.0000)	0.5677*(0.0000)	0.3019*(0.0053)	-0.7090*(0.0000)	1.0000		
INF	-0.7423*(0.0000)	-0.4327*(0.0000)	-0.2638*(0.0153)	0.5648*(0.0000)	-0.6763*(0.0000)	1.0000	
EG	-0.6937*(0.0000)	-0.5451*(0.0000)	-0.2629*(0.0157)	0.8122*(0.0000)	-0.6790*(0.0000)	0.5054*(0.0000)	1.0000

Note: *** p<0.01, * p<0.05, p<0.1. This table presents the results of the pairwise correlation between the variables under study i.e., FinTech, EPU, BV, and GQ. Moreover, the correlation has also been tested for the control variables BSC, INF, and EG*

Table 3 shows the correlation between FinTech, economic policy uncertainty, bank variability, governance quality, control variables bank-specific control, inflation, and economic growth. FinTech, governance quality, inflation, and economic growth are found to be negatively correlated, whereas economic policy uncertainty, bank variability, and bank-specific control are positively correlated.

Antonopoulou et al.; (2022) discuss that economic policy uncertainty and bank variability severely affect FinTech while economic policy uncertainty surges stock market volatility. The results further show that economic policy uncertainty is also positively correlated with bank variability and bank-specific control variables while causing high bank variability and fluctuation in bank assets and loans during high economic policy uncertainty, while negatively correlated with governance quality, inflation, and economic growth. Inflation and bank variability are positively and significantly correlated, whereas governance quality and bank

variability are not significantly correlated., bank-specific control, and economic growth. Bank-specific control and inflation, have negative and positive significant correlations. Inflation influences banks' loans and assets due to changes in the saving behavior of depositors and investors (Singh et al., 2021).

Table 4. VAR Lag Selection Criteria

lag	LL	LR	Df.	P	FPE	AIC	HQIC	SBIC
0	-161.697				3.41969	4.06742	4.07936	4.0972
1	107.212	537.82	1.0000	0.000	0.00422	-2.6303	-2.60642	-2.57075
2	111.246	8.0672*	1.0000	0.005	0.00391	-2.70614	-2.67033	-2.61681*
3	112.756	3.0204	1.0000	0.082	0.00386*	-2.7188*	-2.67114*	-2.59979
4	113.251	.99005	1.0000	0.320	0.00391	-2.70627	-2.64658	-2.55739

Note: LR: test statistic (each test at 5% level), FPE: final prediction error, and LL: lag length at various lag orders. Akaike information criterion, or AIC. Hannan-Quinn information criteria (HQ) and Schwarz information criterion (SC)

The above Table 4, reveals the lag length criteria to employ the NARDL model. According to Schwarz lag selection criteria, the lag length criteria is at 2nd lag, as the minimum lag is suggested (Nguyen et al., 2022)

Table 5. ARDL Model-Sort Run **ARDL Model-Long Run**

FinTech	Coef.	Std.Err.	T	P>t	D.FinTech	Coef.	Std.Err.	T	P>t
FinTech					ADJ				
L1.	1.2740	0.1260	10.1000	0.0000	FinTech				
L2.	-0.2830	0.1390	-2.0300	0.0460	L1.	-0.009	0.055	-0.170	0.868
EPU					LR				
--.	0.0000	0.0000	0.0700	0.9430	EPU	0.0040	0.0280	0.1600	0.8770
L1.	0.0000	0.0000	0.1700	0.8670	BV	0.1070	0.8110	0.1300	0.8950
BV					GQ	-0.3580	3.6890	-0.1000	0.9230
--.	0.0010	0.0020	0.7100	0.4830	BSC	-0.0120	1.6250	-0.0100	0.9940
L1.	0.0000	0.0020	-0.2100	0.8340	INF	-0.4560	2.4290	-0.1900	0.8520
GQ					EG	-1.7230	10.3800	-0.1700	0.8690

--.	0.5780	0.0940	6.1500	0.0000	SR				
L1.	-0.8410	0.1570	-5.3600	0.0000	FinTech				
L2.	0.2600	0.1230	2.1100	0.0390	LD.	0.2830	0.1390	2.0300	0.0460
BSC					EPU				
--.	0.2370	0.0780	3.0200	0.0040	D1.	0.0000	0.0000	-0.1700	0.8670
L1.	-0.4020	0.1230	-3.2700	0.0020	BV				
L2.	0.0900	0.1110	0.8100	0.4230	D1.	0.0000	0.0020	0.2100	0.8340
L3.	0.0750	0.0620	1.2100	0.2320	GQ				
INF					D1.	0.5820	0.1000	5.8100	0.0000
--.	-0.0670	0.0100	-6.4100	0.0000	LD.	-0.2600	0.1230	-2.1100	0.0390
L1.	0.0930	0.0180	5.2300	0.0000	BSC				
L2.	-0.0210	0.0180	-1.1800	0.2410	D1.	0.2370	0.0810	2.9300	0.0050
L3.	-0.0100	0.0090	-1.0900	0.2790	LD.	-0.1650	0.0840	-1.9700	0.0540
EG					L2D.	-0.0750	0.0620	-1.2100	0.2320
--.	0.0390	0.0280	1.4200	0.1600	INF				
L1.	-0.0860	0.0430	-2.0000	0.0500	D1.	-0.0620	0.0120	-5.3000	0.0000
L2.	0.0310	0.0280	1.1000	0.2780	LD.	0.0300	0.0140	2.2100	0.0310
_cons	0.1670	0.0620	2.7000	0.0090	L2D.	0.0100	0.0090	1.0900	0.2790
χN	7.77(0.0206)				EG				
χSC	169.861(0.0000)				D1.	0.0550	0.0280	2.0100	0.0480
χH	1.73(0.1888)				LD.	-0.0310	0.0280	-1.1000	0.2780
χREMSEY	49.54(0.0000)				_cons	0.1670	0.0620	2.7000	0.0090

Note: the coefficients and P values of the ARDL model address the short and long-run relationship between FinTech and GQ. The diagnostics χN, χSC, χH, and χREMSEY reveal the results of normality, serial correlation, heteroscedasticity, and misspecification respectively.

Table 5, sheds light on the results of the ARDL model with a symmetric relationship between FinTech and governance quality while an insignificant relationship with economic policy uncertainty and bank variability P>5%. During the short run, there is a significant positive

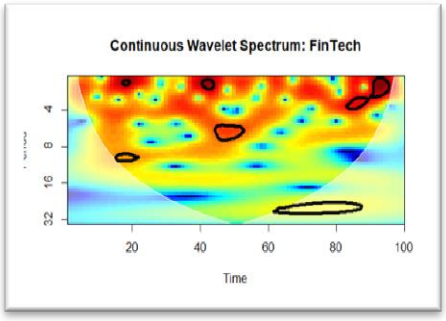
association between FinTech and lags at a P value <5%. While inflation and bank-specific control are also positively associated with FinTech during the short run, in the long run, GQ has a symmetric association with FinTech with P<5%.

Furthermore, governance quality, inflation, and bank-specific control variables are positively associated with FinTech (Cárceles et al 2019). The proxies of governance quality include regulatory quality and government effectiveness (Lee et al., 2020), which have a positive association with FinTech. The State Bank of Pakistan provides certain regulations for easy access to digital banking and documentation[xxiv]. The strong regulatory quality and effective government policies provide confidence to overseas clients and enhance foreign direct investment, or remittances, which reduces stock market uncertainty and boosts FinTech (Uddin et al., 2019).

Continuous Wavelet Analysis

The horizontal axis represents time, and the vertical axis represents period and frequency (the lower the frequency, the higher the scale), areas where the two-time series co-vary are found in the time-frequency domain. Colder hues (blue) indicate less reliance between the series, whereas warmer hues (red) indicate regions with a strong correlation. The cold areas outside of the important areas are independent of the series and signify time and frequencies. Wavelet transform analysis's primary function is to combine time and frequency analysis; however, because frequency information has different resolutions at each level, there are complications in explaining this scenario (Afshan et al., 2018; Silik et al., 2021). Because continuous wavelet analysis provides more observable and visible frequency data, it is comparatively easier to understand (Wirsing, 2020).

Figure 1

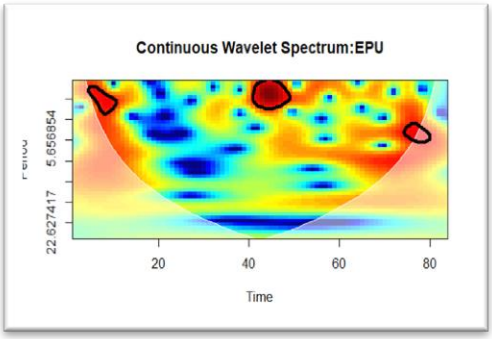


Note: The thick black contour reveals a significance level of 5% against the noise in red color. The color code ranges from red (high power) and blue (low power)

In 2014, Pakistani commercial banks introduced and attracted existing customers to FinTech services and these services were still in an immature stage. Figure 1, reveals an insignificant relationship with black contour with yellow. However, with time at the end of the sample period 2020, FinTech services significantly co-move with other variables under study with a warm red color code. The findings indicate that, concerning FinTech, we have a rather steady variance in the long and very long runs about the short and medium runs. We observe that the medium scale has a high variance as well. These results imply significant variations in the growth of tourism happen over a short period, mostly in the run-in medium. Furthermore, a

significant substantial short- and medium-term volatility (Li et al., 2018). These findings suggest that the variation in the FinTech complications might also arise in the short and medium term

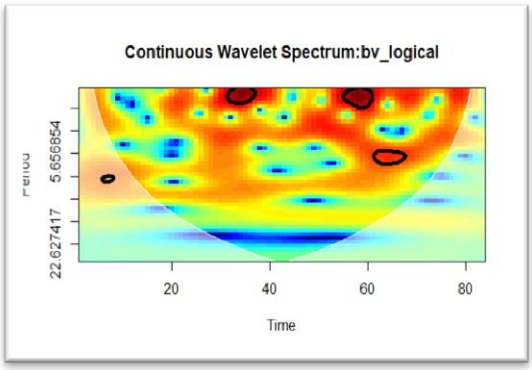
Figure 2.



Note: The thick black contour reveals a significance level at 5% against the noise in red color. The color code ranges from red (high power) and blue (low power)

Economic policy uncertainty is a well-established macroeconomic indicator that shows a significant relationship with FinTech services. However, fig 2 shows that in 2020, economic policy uncertainty increased and changed its behavior and the reason could be the pandemic as COVID-19 shook the overall economic and financial system (Rubbaniy et al., 2023).

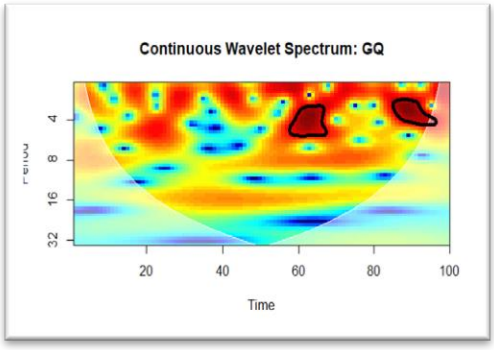
Figure 3.



Note: The thick black contour reveals a significance level at 5% against the noise in red color. The color code ranges from red (high power) and blue (low power)

Many internal and external factors impact increased bank variability such as interest rates that are significantly impacted by central bank decisions towards bank service charges. Increasing inflation can have an influence on consumers' purchasing power, which can then have an impact on demand for and repayment capacity for loans, ultimately affecting bank profitability. Bank-specific factors like size, loans, deposits, and profit. Figure 2.4, shows high co-movement between FinTech services and bank variability while, near 2020, the behavior has been changed by showing less warm red. The literature explored a high bank variability and contraction in banking services due to COVID-19 (Baek et al., 2020; Kusumahadi & Permana, 2021; Chowdhury et al., 2022).

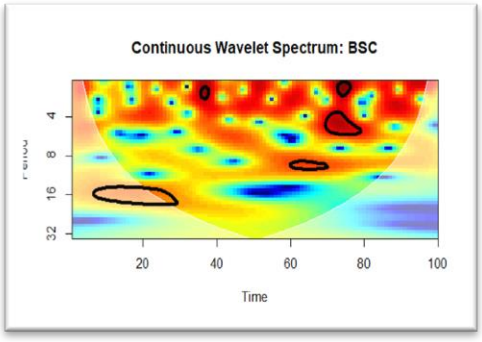
Figure 4.



Note: The thick black contour reveals a significance level at 5% against the noise in red color. The color code ranges from red (high power) and blue (low power)

The governance quality proxy by "World governance indicators" is used in literature. We have selected two indicators "regulatory quality" and "government effectiveness" based on research. Figure 4, sheds light on strong significant co-movement between FinTech and governance quality with a warm red color. Governance quality demonstrates the capacity of the government to create and carry out strict laws and rules that support and encourage the growth of the private sector. Furthermore, it evaluates the government's commitment to enforcing policies, and public services and civil service quality that extend independence from political events (Yin, 2019; Eldomiaty et al., 2020).

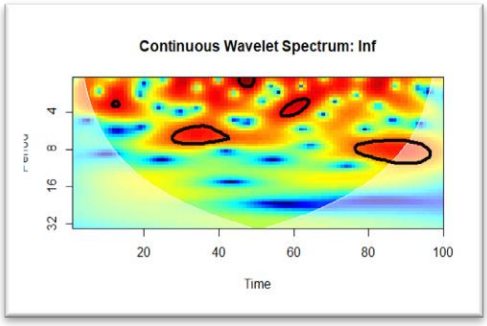
Figure 5.



Note: The thick black contour reveals a significance level at 5% against the noise in red color. The color code ranges from red (high power) and blue (low power)

Figure 5 reveals mixed co-movement of FinTech with bank-specific control variables as sometimes these internal factors affect FinTech services significantly. However, the contour shows that sometimes bank-specific control variables do not co-move with the bank's FinTech services (Banna et al., 2021).

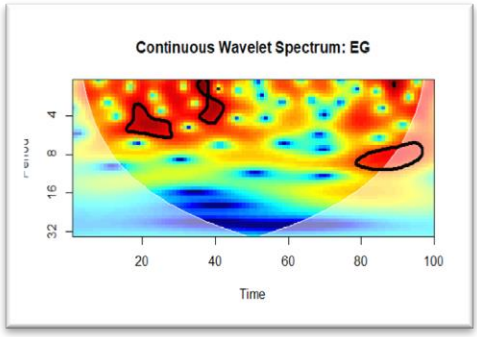
Figure 6.



Note: The thick black contour reveals a significance level at 5% against the noise in red color. The color code ranges from red (high power) and blue (low power)

The demand for and characteristics of the intricate relationship influences digital financial services between inflation and FinTech (Katırcıoglu et al., 2020). During periods of inflation, both consumers and businesses frequently look for more effective strategies to control growing expenses. During times of high inflation, digital banking becomes more appealing since it provides affordable options for handling finances, including reduced transaction fees, simple account access, and tools for financial planning and budgeting. Costs for tangible products and services, such as those associated with traditional banking (such as branch operations), may rise as a result of high inflation. Because of this, customers might switch to digital banking to save money on expenses like service fees and transportation that come with traditional banking (Katırcıoglu, et al., 2021).

Figure 7.



Note: The thick black contour reveals a significance level at 5% against the noise in red color. The color code ranges from red (high power) and blue (low power)

Though the impact of economic growth on FinTech services varies depending on some factors, such as the level of digital infrastructure, the regulatory environment, and the inclusiveness of digital banking initiatives, FinTech services are major drivers of economic growth (Chinoda & Kapingura, 2024), especially when it comes to financial inclusion, efficiency, innovation, and market expansion (Nguyen, & Le, 2022). In Figure 8, a significant

co-movement has been revealed between FinTech services of Pakistani commercial banks and economic growth during 2014-2020 with a warm red color code.

Conclusion and Recommendations

According to research, between 2014 and 2020, the quality of governance, bank variability, and economic policy unpredictability had a substantial impact on FinTech services in Pakistani commercial banks. The results of this study are consistent with earlier research because the relationship with other banking services has been the subject of a substantial body of literature. Since FinTech services are still in their infancy in commercial banks and internet and mobile banking data are nonexistent or scarce in Pakistan, there hasn't been as much research in this area. Pakistan's poor financial literacy rate is another factor contributing to the paucity of research on FinTech and the sluggish adoption of these services. While the majority of these services are utilized in cities, digital banking is still not available to people living in rural areas.

Furthermore, advanced econometric techniques have been used in place of conventional analysis techniques. These methods can be applied to problems involving non-stationary time series and integration order. Therefore, the continuous wavelet transform framework has been used to test the association. With this new approach, time series at different frequencies may be broken down more easily and precise findings based on short, medium, and long runs are obtained for the different frequencies. The unit root test, correlation analysis, autoregressive distributed lag model (ARDL) (Fernandes et al., 2021), and continuous wavelet power spectrum were employed in the current study to evaluate the relationship between FinTech EPU, BV, and GQ using monthly data. The short- and long-term linear relationship between FinTech and governance quality is examined by the ARDL method.

There is a negligible symmetric association between bank variability and economic policy uncertainty and fintech. Furthermore, the wavelet coherence approach's Results verify that the factors considerably affect each other throughout the short, medium, and long terms (Adebayo, 2020; Baidoo et al., 2023; Adebayo et al., 2024). We conclude, to justify our hypothesis that FinTech, economic policy uncertainty (He & Shen 2021; Ozili, 2021; Cheng & Masron, 2023), governance quality (Haini & Pang 2022; Wu, 2023; Jain & Sahu, 2024), and bank variability (Umar et al., 2021; Chowdhury et al., 2022) are associated and co-move. Additionally, there is a substantial correlation between Fintech and the control factors (Banna et al., 2020; Ikpeso, 2021; Bernard, 2022; Khattak et al., 2023). The study's findings are consistent with previous research.

These conclusions are intriguing, given the number of unanswered questions. In the future, FinTech may be used to investigate additional factors like stock market crashes, political unrest, terrorism, and geopolitical risk. More studies in this area would be necessary to fully comprehend the dynamic linkages between technology innovation, policy uncertainty, governance quality, and bank variability in Pakistan. The findings might provide important insights for improving financial stability, encouraging creativity, and boosting the standard of governance in the financial sector. Furthermore, the government must offer FinTech to remote parts of Pakistan and offer instruction to raise financial literacy. It is advised that the State Bank of Pakistan implement robust measures to address economic policy uncertainties and provide additional programs for foreign investors, such as the Roshan Pak account.

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[xvi] *Financial inclusion incudes overall FinTech services*
[xvii] *Islamic, conventional, commercial or investment banking.*
[xviii] *Control variables: Macroeconomic Factors (inflation & economic growth). Bank specific Factors (Size, Total assets to total loans ratio, total loans, growth)*
[xix] *Q J Econ 131(4):1593–1636, 2016*
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[xxii] *The stock price data, later on converted in to returns, of 19 listed commercial banks have been obtained from PSX at daily frequency. Standard deviation of returns has been calculated on monthly basis and aggregate the results for bank variability.*

[xxiii] *https://diposit.ub.edu/dspace/bitstream/2445/131064/3/memoria.pdf*

[xxiv] *https://www.sbp.org.pk/bprd/2022/C1-Annex.pdf*