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The Impact of Cryptocurrencies on Financial Stability and Bank Performance: Evidence from Conventional Banking

1. Ali Asghar. Tahanpour: Department of Economics, CT.C., Islamic Azad University, Tehran, Iran
2. Mohammadreza. Mirzaei Nejad*: Department of Economics, CT.C., Islamic Azad University, Tehran, Iran
3. Khashayar. Seyed-Shokri: Department of Economics, CT.C., Islamic Azad University, Tehran, Iran

*corresponding author's email: moh.mirzaeenejad@iauctb.ac.ir

ABSTRACT

The present study aimed to investigate the nonlinear effects of cryptocurrencies on financial stability and bank performance in the conventional banking sector of Islamic countries with dual banking systems. Accordingly, data pertaining to the conventional banking sectors of Turkey, Pakistan, Azerbaijan, Malaysia, Jordan, and Algeria over the 2013–2024 period were collected and analyzed using a Panel Smooth Transition Regression (PSTR) model with a logistic transition function. In the financial stability model, financial development was selected as the transition variable, with an estimated threshold value of 0.217254 and a slope parameter of 0.618469. In the bank performance model, the estimated threshold value of financial development was 0.964102, while the slope parameter was 6.675325. According to the financial stability model, cryptocurrency market capitalization and cryptocurrency trading volume relative to GDP exert positive and statistically significant effects on financial stability in both the linear and nonlinear components. This finding may suggest that, within the banking systems examined, cryptocurrency market expansion has contributed to greater financial stability—at least under the conditions investigated—through the development of digital services, increased competition, improvements in payment infrastructure, and the creation of new revenue-generating opportunities. In contrast, Bitcoin price volatility has a negative and statistically significant effect on financial stability in the nonlinear component, indicating increased market risk, a greater possibility of shock transmission, and heightened uncertainty associated with greater volatility in digital assets. Financial development, bank size, institutional quality, and economic growth also generally exert positive and statistically significant effects on financial stability, whereas inflation exhibits a negative and statistically significant effect in the nonlinear regime. In the bank performance model, cryptocurrency market capitalization and cryptocurrency trading volume relative to GDP have positive and statistically significant effects on banks' return on assets in both regimes. Bitcoin volatility also exerts a negative and statistically significant effect on bank performance in both regimes. Therefore, increased cryptocurrency activity, when accompanied by adequate infrastructure and an effective regulatory framework, may improve the performance of conventional banks through enhanced operational efficiency, expansion of fee-based income, and greater financial innovation; however, severe cryptocurrency price volatility remains a threat to bank profitability. The effect of financial development on bank performance is negative in the linear regime but positive in the nonlinear regime, indicating the decisive role of the level of financial development in transforming the effects of cryptocurrencies from pressures on profit margins and intensified competition into opportunities for greater efficiency and revenue generation. Inflation has a negative and statistically significant effect on bank performance in both regimes, whereas bank size, institutional quality, and economic growth exhibit positive and statistically significant effects in the nonlinear component. Tests of autocorrelation, heteroskedasticity, and coefficient stability confirmed the statistical validity and adequacy of the estimated model specifications.

Keywords: cryptocurrencies, financial stability, bank performance, financial development, institutional quality, conventional banking



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Introduction

The rapid expansion of cryptocurrencies and other forms of digital money has transformed the architecture of contemporary financial systems and has created new challenges for conventional banking institutions, financial regulators, and monetary authorities. Cryptocurrencies differ fundamentally from traditional bank-based money because they rely on decentralized or distributed technological infrastructures, frequently operate outside conventional payment and settlement channels, and can facilitate cross-border transfers with limited dependence on traditional financial intermediaries. Their growing role has consequently generated a debate over whether digital assets should primarily be regarded as a source of financial innovation, an alternative investment class, a new means of payment, or a potential source of systemic instability. The technological foundations of cryptocurrencies have accelerated the development of monetary technologies and have altered perceptions of the functions traditionally performed by money, financial intermediaries, and payment institutions (1). At the same time, the legal and economic status of cryptocurrencies remains contested because digital assets do not always satisfy the conventional characteristics of money, legal tender, or bank-based financial instruments (2). Legal scholarship has similarly emphasized that the classification of cryptocurrencies as currency, property, consideration, or a means of payment depends on the institutional and legal framework within which they operate (3). This ambiguity is particularly relevant to banking systems because the regulatory treatment of cryptocurrencies influences banks' ability to provide custody, payment, settlement, lending, collateralization, and investment services related to digital assets. The controversy surrounding the extension of the legal concept of currency to cryptocurrencies demonstrates that their integration into the formal financial system is not simply a technological issue but also an institutional and regulatory challenge (4). Comparative legal analysis further suggests that the legitimacy and enforceability of cryptocurrency transactions are increasingly determined by the interaction between domestic financial regulation and rapidly evolving international practices (5).

The growth of cryptocurrency markets has important implications for financial stability because digital assets are increasingly interconnected with conventional financial institutions, capital markets, and household investment portfolios. Financial stability generally refers to the capacity of the financial system to absorb shocks, efficiently allocate resources, and maintain its core functions even during periods of market stress. From this perspective, the effect of cryptocurrencies is theoretically ambiguous. On the one hand, digital assets can enhance financial innovation, increase competition, support payment efficiency, promote financial inclusion, and generate new sources of fee-based income for banks. On the other hand, their extreme price volatility, speculative trading dynamics, liquidity risks, regulatory uncertainty, and cross-market spillovers may amplify financial fragility. Financial fragility is particularly important in developing and emerging economies, where relatively shallow markets, weaker regulatory institutions, inflationary pressures, and external financial constraints may increase the sensitivity of financial systems to unconventional shocks (6). The possibility that cryptocurrency-market disturbances may spill over into conventional financial markets has therefore become a major issue in the financial stability literature. Empirical evidence suggests that cryptocurrency markets are dynamically linked with traditional financial markets and that the direction and magnitude of these relationships vary across time and market conditions (7). The existence of such dynamic causal relationships implies that cryptocurrencies can no longer be treated as an isolated asset class, particularly as banks, institutional investors, fintech firms, and households become increasingly exposed to digital assets.

A central characteristic of cryptocurrency markets is their exceptionally high volatility. Cryptocurrency prices respond rapidly to investor sentiment, regulatory announcements, macroeconomic uncertainty, geopolitical events, technological developments, and shifts in liquidity conditions. Early research on cryptocurrency forecasting demonstrated that incorporating user sentiment can improve the prediction of cryptocurrency price volatility, indicating the importance of behavioral factors in these markets (8). More recent evidence confirms that cryptocurrency volatility is characterized by complex stochastic dynamics that differ from those of many conventional financial assets (9). Furthermore, the market exhibits time-varying network structures in which volatility can be transmitted among cryptocurrencies and potentially amplified through interconnected trading relationships (10). Behavioral finance provides an additional explanation for these patterns, emphasizing that investor biases, attention, herding, overreaction, anchoring, and speculative behavior can intensify cryptocurrency-market fluctuations (11). These behavioral mechanisms may also affect conventional financial institutions indirectly by influencing the liquidity and valuation of cryptocurrency-related exposures, changing customer portfolio decisions, and increasing uncertainty in markets with strong digital-asset participation. Investor behavior in conventional capital markets already plays an important role in correcting or reinforcing mispricing around information events (12), and similar behavioral channels may become even stronger in cryptocurrency markets, where information asymmetry and speculative participation are comparatively pronounced.

The interconnectedness between digital assets and traditional financial markets raises particular concerns regarding shock transmission and systemic risk. Quantile-based evidence indicates that spillovers between cryptocurrencies and regulated financial markets are heterogeneous across market states and become particularly important during periods of extreme stress (13). This suggests that the effects of cryptocurrency expansion on financial stability may be nonlinear rather than constant across different levels of market development or economic conditions. Similarly, research on spillovers between green and conventional cryptocurrencies demonstrates that risk transmission can be asymmetric and can depend on both geopolitical and financial risk environments (14). Evidence from the Russia–Ukraine war further shows that geopolitical shocks can alter the safe-haven characteristics and pricing behavior of cryptocurrencies, reinforcing the idea that digital assets can respond differently across crisis and non-crisis regimes (15). Studies of return and volatility spillovers between green cryptocurrencies and G7 financial markets likewise indicate that digital assets are increasingly embedded in wider financial networks (16). Such interconnectedness is directly relevant to banks because banks may face cryptocurrency-related risks through customer behavior, investment exposures, payment services, fintech partnerships, deposit substitution, or changes in liquidity demand. Theoretical and empirical evidence further indicates that sequential attention cycles among cryptocurrency investors can transmit instability from digital-asset markets to broader financial markets (17). Accordingly, the effect of cryptocurrencies on banking stability is likely to depend not merely on the size of the cryptocurrency market but also on volatility conditions, trading intensity, and the financial system's ability to absorb market shocks.

Despite these risks, cryptocurrency expansion may also provide significant opportunities for conventional banks. Competition from decentralized and fintech-based financial services can pressure traditional banks to modernize payment infrastructures, automate settlement mechanisms, reduce transaction costs, and develop digital financial products. Strategic planning for cryptocurrency development within national banking systems has therefore increasingly emphasized the need for banks to combine technological innovation with risk management and regulatory adaptation (18). The diffusion of cryptocurrencies can also encourage banks to expand non-interest

revenue through custody, transaction processing, brokerage, advisory services, and digital-asset infrastructure. In addition, digital assets may become relevant to bank lending if they can be legally and operationally accepted as collateral. The feasibility of pledging cryptocurrencies as collateral has attracted increasing attention, although significant challenges remain regarding valuation, volatility, legal enforceability, custody, and liquidation risk (19). These issues parallel developments in decentralized finance, where liquidation mechanisms can directly influence lending behavior and credit supply (20). Consequently, the relationship between cryptocurrency development and bank performance is unlikely to be exclusively negative. Under appropriate technological and regulatory conditions, digital assets may improve efficiency, diversify bank income, and create new forms of financial intermediation.

The expansion of digital currencies also has broader implications for monetary policy and the architecture of banking systems. The increasing popularity of cryptocurrencies has encouraged central banks to reassess the design of money, payment systems, and monetary transmission mechanisms. Comparative research indicates that digital currencies may reshape banking business models and alter the implementation of monetary policy by influencing deposit structures, payment behavior, liquidity management, and the role of financial intermediaries (21). Policymaking models for cryptocurrency regulation have therefore increasingly sought to balance financial innovation with trade development, monetary sovereignty, and systemic stability (22). Central bank digital currencies represent one institutional response to these developments. Research on the implementation of central bank digital currencies emphasizes both substantial opportunities and important technical, legal, and regulatory challenges (23). Similarly, news and policy signals concerning central bank digital currencies can affect financial markets by changing expectations about future monetary and payment-system structures (24). A systematic review of the financial-stability consequences of central bank digital currencies further demonstrates that digitalization can generate both stabilizing and destabilizing channels, depending on the design of the currency, the structure of banking intermediation, and the behavior of depositors (25). Thus, the broader digitalization of money highlights the importance of evaluating cryptocurrency effects within the institutional structure of existing banking systems rather than treating digital assets as independent from conventional finance.

The potential macroeconomic contribution of digital currencies has also attracted attention because their development may influence economic growth, capital formation, transaction efficiency, and financial inclusion. Evidence from selected countries suggests that digital currency development can affect economic growth through changes in payment efficiency, investment opportunities, and financial-market participation (26). However, the benefits of digitalization are likely to depend on financial development, institutional quality, and macroeconomic stability. Stronger financial institutions may enable banks and regulators to integrate cryptocurrency-related innovations while controlling market and liquidity risks, whereas weaker institutional environments may experience higher vulnerability to speculative capital flows, fraud, regulatory arbitrage, and operational risk. This distinction is especially relevant in dual banking systems, where conventional and Islamic banks coexist within a common macroeconomic and regulatory environment but may differ in risk structures, balance-sheet composition, and intermediation models. Evidence on dual banking systems demonstrates that institutional conditions, including corruption and governance quality, can influence bank risk-taking behavior and alter the transmission of financial risks (27). Institutional quality may therefore condition the extent to which cryptocurrency-market expansion contributes to innovation or, alternatively, intensifies instability.

Financial development is another factor that can alter the impact of cryptocurrencies on banks. In relatively underdeveloped financial systems, cryptocurrencies may compete directly with banks for liquidity, savings, and

payment flows, thereby reducing traditional intermediation margins. As financial systems develop, however, banks may gain stronger technological capabilities, deeper capital markets, improved risk-management systems, and more sophisticated regulatory structures, enabling them to integrate digital-asset activity more productively. This suggests a possible threshold effect in which the impact of cryptocurrency activity changes once financial development reaches a particular level. Such nonlinear dynamics are consistent with evidence from financial-market research showing that connectedness, diversification benefits, and spillover effects vary substantially across market states rather than remaining constant over time (28). Cryptocurrency markets similarly display regime-dependent behavior, with market conditions influencing trust, adoption, and transaction behavior. Research on cryptocurrency use in consumer markets, for example, shows that market volatility can significantly affect trust and adoption decisions (29). Therefore, a nonlinear framework may offer a more appropriate representation of the relationship between cryptocurrency development, bank stability, and bank profitability.

The institutional and regulatory response to cryptocurrencies is also critical because uncertainty regarding the legal treatment of digital assets can directly influence banks' willingness to enter cryptocurrency-related markets. Regulatory clarity can reduce compliance uncertainty, strengthen consumer protection, and improve risk management, while regulatory ambiguity may discourage productive innovation or push cryptocurrency activities outside the formal financial system. Domestic legal debates surrounding the economic and juridical treatment of cryptocurrencies illustrate the difficulty of fitting decentralized digital assets into existing financial regulations (2). At the same time, jurisprudential and legal analyses indicate that the legitimacy of cryptocurrency transactions depends on how concepts such as ownership, exchange, monetary value, and contractual validity are interpreted within national legal systems (5). The legal treatment of cryptocurrencies as exchange instruments or means of payment further affects the extent to which banks can integrate them into payment and settlement operations (3). The regulatory question is therefore closely connected to financial stability: clearer legal definitions may enable banks and regulators to identify risks more accurately, establish prudential requirements, and develop appropriate supervisory frameworks.

Another important dimension concerns the role of market depth and cryptocurrency transaction intensity. Cryptocurrency market capitalization represents the overall economic size of the digital-asset sector, while trading volume relative to GDP captures the intensity of cryptocurrency activity compared with the size of the national economy. These dimensions may generate different effects on banking systems. A larger cryptocurrency market can create competition for deposits and investment funds, but it can also expand demand for digital financial services and create new sources of transactional income. Higher trading volume may similarly increase payment flows and demand for custody and settlement services while simultaneously increasing exposure to market volatility. The economic significance of these channels depends on the ability of conventional banks to adapt their business models. Qualitative evidence concerning digital currencies and banking models indicates that technological transformation can affect both the cost structure and revenue composition of banks (21). Meanwhile, strategic analyses of cryptocurrency adoption in banking emphasize that successful integration requires coordinated technological, organizational, regulatory, and risk-management capabilities (18).

The interaction between cryptocurrency volatility and financial-market behavior further reinforces the need for a nonlinear analytical framework. Studies of cryptocurrency-market dynamics show that volatility can intensify rapidly during periods of uncertainty, while investor attention and sentiment can amplify market movements (11). Network-based evidence indicates that volatility propagation across digital assets changes over time, suggesting that the

systemic implications of cryptocurrency exposure cannot be adequately evaluated using purely linear models (10). Furthermore, spillover effects between cryptocurrencies and regulated markets differ across quantiles and stress conditions (13). These findings support the proposition that the relationship between cryptocurrencies and conventional banking may depend on threshold conditions, such as the level of financial development. Under lower levels of financial development, cryptocurrency expansion may exert stronger competitive or liquidity pressures on banks; under higher levels, improved infrastructure and institutional capacity may allow banks to capture benefits from digital innovation while containing associated risks.

The literature therefore presents a mixed picture. Cryptocurrencies can enhance financial innovation, diversify investment opportunities, support payment efficiency, and stimulate technological modernization, but they can also amplify volatility, create new channels of contagion, challenge regulatory frameworks, and place pressure on traditional banking intermediation. These competing effects are particularly important in Islamic countries with dual banking systems, where conventional banks operate alongside Islamic banks and are exposed to distinctive regulatory, institutional, and market structures. Existing studies have examined cryptocurrency volatility (9), cross-market connectedness (7), spillovers under regulated environments (13), geopolitical and asymmetric risk transmission (14, 15), behavioral dynamics (11), banking and monetary policy adaptation (21), and institutional aspects of digital-asset regulation (4, 19). Nevertheless, comparatively limited empirical attention has been devoted to examining simultaneously the effects of cryptocurrency market capitalization, Bitcoin volatility, and cryptocurrency trading intensity on both financial stability and conventional-bank performance while allowing these effects to vary nonlinearly according to the level of financial development. This gap is particularly important because the selected countries—Turkey, Pakistan, Azerbaijan, Malaysia, Jordan, and Algeria—represent heterogeneous financial systems in which conventional banking operates within dual banking environments and where levels of financial development, institutional quality, inflation, economic growth, and banking-sector structure differ substantially.

Accordingly, the aim of this study is to investigate the nonlinear effects of cryptocurrency market capitalization, Bitcoin price volatility, and cryptocurrency trading volume relative to GDP on financial stability and the performance of conventional banks in selected Islamic countries with dual banking systems during 2013–2024, using a Panel Smooth Transition Regression model with financial development as the transition variable.

Methods and Materials

Following the studies of Heitman et al. (2025), Afzal (2025), Al-Saadi (2025), and Bouri (2024), the present study evaluates the impact of cryptocurrencies on financial stability and bank performance in conventional banking. Given that the dependent variables are financial stability and bank performance, while the explanatory variables include cryptocurrency market capitalization, Bitcoin price volatility, cryptocurrency trading volume relative to GDP (Crypto Trading Volume/GDP), bank size, financial development, and institutional quality, the general form of the PSTR model is specified as follows:

Model 1: Financial Stability

$$Z\text{-score}_t = \alpha_0 + \beta_1 MC_t + \beta_2 BV_t + \beta_3 CT_t + \beta_4 FD_t + \beta_5 INF_t + \beta_6 SIZE_t + \beta_7 IQ_t + \beta_8 GROWTH_t + (\theta_1 MC_t + \theta_2 BV_t + \theta_3 CT_t + \theta_4 FD_t + \theta_5 INF_t + \theta_6 SIZE_t + \theta_7 IQ_t + \theta_8 GROWTH_t) F(S_t, \gamma, c) + u_t \quad (1)$$

Model 2: Banking System Performance

$$BP_t = \alpha_0 + \beta_1 MC_t + \beta_2 BV_t + \beta_3 CT_t + \beta_4 FD_t + \beta_5 INF_t + \beta_6 SIZE_t + \beta_7 IQ_t + \beta_8 GROWTH_t \quad (2)$$
$$+(\theta_1 MC_t + \theta_2 BV_t + \theta_3 CT_t + \theta_4 FD_t + \theta_5 INF_t + \theta_6 SIZE_t + \theta_7 IQ_t + \theta_8 GROWTH_t) F(S_t, \gamma, c) + u_t$$

Financial Stability (Z-score): To assess financial stability, the banking stability index commonly known as the Z-score is employed. In this measure, bank stability is calculated as the sum of the capital adequacy ratio and return on assets, divided by the standard deviation of return on assets. The larger this index, the lower the probability of bank instability or failure; in other words, a higher value indicates a more stable banking condition.

$$\text{Bank Stability} = \ln(Z\text{-score}) = \ln\left(\frac{ROA + \text{Capital Ratio}}{\sigma(ROA)}\right)$$

Banking System Performance (BP): Return on assets (ROA), defined as profit divided by total assets, is used as the indicator of banking system performance.

Cryptocurrency Market Capitalization (MC): Cryptocurrency market capitalization refers to the aggregate market value of all active cryptocurrencies over a specified period, measured as the total value of the cryptocurrency market in U.S. dollars in each year. An increase in this variable indicates greater cryptocurrency market activity and may represent a potential threat to bank liquidity and funding resources (Afshari et al., 2025).

Bitcoin Volatility (BV): Bitcoin volatility refers to the degree of variation in the price of Bitcoin over a specified period and is measured using the standard deviation of annual Bitcoin returns. Higher volatility indicates greater risk for banks exposed, directly or indirectly, to digital asset markets.

Cryptocurrency Trading Volume Relative to GDP (CT): This variable represents the ratio of total cryptocurrency trading volume to a country's gross domestic product. It is calculated as the total cryptocurrency trading volume during a given period divided by GDP during the same period. The indicator reflects the intensity of cryptocurrency activity relative to the overall size of the economy and provides a measure of the potential pressure exerted on bank liquidity.

FD: Financial development is measured using the financial market development indicator, proxied by bank credit extended to the private sector.

SIZE: Bank size, measured as the natural logarithm of total bank assets.

INF: Inflation.

Growth: The gross domestic product growth rate. Gross domestic product represents the market or monetary value of all final goods and services produced within a country's borders during a specified period.

IQ: Institutional quality refers to the degree of transparency, effectiveness, and efficiency of a country's legal and regulatory framework in the financial and banking sectors. It is measured using World Bank indicators or Doing Business reports relating to institutional quality and banking-system efficiency. Higher institutional quality contributes to greater bank stability and mitigates the adverse effects of cryptocurrencies (Miro et al., 2025).

To examine the characteristics of the PSTR model with a logistic transition function, following van Dijk (1999), it is assumed that the dependent variable is solely a function of its own lagged values. Under a two-regime transition function, the following equations are obtained:

$$Z\text{-score}_t = \left(\theta_0 + \theta_1 Z\text{-score}_{t-1} + \cdots + \theta_p Z\text{-score}_{t-p}\right)$$
$$+\left(\phi_0 + \phi_1 Z\text{-score}_{t-1} + \cdots + \phi_p Z\text{-score}_{t-p}\right) G(B, V_t, \gamma c) + u_t$$

$$BP_t = \left(\theta_0 + \theta_1 BP_{t-1} + \cdots + \theta_p BP_{t-p}\right) \qquad (6)$$
$$+\left(\phi_0 + \phi_1 BP_{t-1} + \cdots + \phi_p BP_{t-p}\right) G(B, V_t, \gamma c) + u_t$$

The resulting specification is referred to as a two-regime PSTR model. The location parameter $c$represents the point of transition between the two limiting regimes, $G(B, V_t, \gamma c) = 0$and $G(B, V_t, \gamma c) = 1$, where at the transition midpoint $G(B, V_t, \gamma c) = 0.5$. The parameter γrepresents the speed of transition between regimes, with larger values of γindicating a more rapid regime transition.

The statistical data used in this study cover the period from 2013 to 2024. The statistical population comprises Islamic countries with dual banking systems. More specifically, the study examines the conventional banking sectors of Turkey (dual banking system), Pakistan (dual banking system), Azerbaijan (dual banking system), Malaysia (dual banking system), Jordan (dual banking system), and Algeria (dual banking system).

Findings and Results

The empirical analysis began by examining the stationarity properties of the study variables using panel unit root tests. Testing for stationarity is a necessary preliminary step before estimating the econometric models because the use of nonstationary variables may lead to spurious regression results. Accordingly, the Levin–Lin–Chu (LLC) panel unit root test was applied to all variables. As reported in Table 1, the null hypothesis of a unit root was rejected for all variables at conventional significance levels. Therefore, bank performance (BP), Bitcoin volatility (BV), cryptocurrency trading volume relative to GDP (CT), financial development (FD), economic growth ($GROWTH$), inflation (INF), institutional quality (IQ), cryptocurrency market capitalization (MC), bank size ($SIZE$), and financial stability ($ZSCORE$) were stationary at level, $I(0)$.

Table 1. Panel Unit Root Test Results for the Selected Countries with Conventional Banking

Variable	LLC Test Statistic	*p*-value	Order of Integration
BP	-3.00956	0.0013	$I(0)$
BV	-2.05525	0.0199	$I(0)$
CT	-1.82043	0.0343	$I(0)$
FD	-1.89579	0.0290	$I(0)$
GROWTH	-2.71127	0.0034	$I(0)$
INF	-5.66867	0.0000	$I(0)$
IQ	-3.61852	0.0001	$I(0)$
MC	-2.84614	0.0022	$I(0)$
SIZE	-2.97659	0.0015	$I(0)$
ZSCORE	-3.62162	0.0001	$I(0)$

To investigate the existence of a long-run equilibrium relationship among the variables included in the regression models, the Kao panel cointegration test was employed. The test was performed separately for the financial stability and bank performance models. The results are presented in Table 2.

Table 2. Results of the Kao Panel Cointegration Test

Model	Kao Test Statistic	*p*-value
Financial stability model	-2.332360	0.0098
Bank performance model	-10.21640	0.0000

For the selected countries with conventional banking, the null hypothesis of no cointegration was rejected at the 95% confidence level for both models. Thus, the alternative hypothesis indicating cointegration among the variables

was supported, confirming the existence of a statistically significant long-run relationship among the variables included in both the financial stability and bank performance specifications.

Before estimating the financial stability model, the existence of a linear or nonlinear relationship among the variables was examined. In the relevant tests, the null hypothesis assumes a linear model, whereas the alternative hypothesis corresponds to either a logistic PSTR specification with $m = 1$or an exponential PSTR specification with $m = 2$, where $m$denotes the number of location parameters determining the regimes.

The results of the linearity tests demonstrated that the null hypothesis of linearity was rejected. The Wald test yielded an F-statistic of 3.502 with $p < .001$, the Fisher test produced an F-statistic of 2.335 with $p < .001$, and the likelihood-ratio test yielded a statistic of 2.607 with $p = .008$. Consequently, the relationship between cryptocurrency-related variables and financial stability in the selected countries with conventional banking was nonlinear, supporting the use of the PSTR approach.

Following confirmation of nonlinearity, the adequacy of a single transition function was examined. Following González et al. (2005) and Colletaz and Hurlin (2006), the null hypothesis of a PSTR model with one transition function, $H_0: r = 1$, was tested against the alternative hypothesis requiring at least two transition functions, $H_1: r = 2$. Under the specification with one threshold ($M = 1$), the LM-Wald, LM-Fisher, and likelihood-ratio statistics were 1.480 ($p = .738$), 1.871 ($p = .841$), and 1.785 ($p = .743$), respectively. Under the specification with two thresholds ($M = 2$), the corresponding statistics were 1.330 ($p = .688$), 1.417 ($p = .772$), and 1.125 ($p = .821$). The null hypothesis was therefore not rejected in either specification, indicating that one transition function was sufficient to capture the nonlinear effects of cryptocurrencies on financial stability.

After establishing the adequacy of one transition function, the optimal number of threshold parameters was determined. PSTR models corresponding to one- and two-threshold specifications were estimated and compared using the residual sum of squares, Schwarz information criterion, and Akaike information criterion. According to these criteria, the specification with one transition function and one threshold provided the optimal representation of the nonlinear relationship among the variables. Accordingly, a PSTR model with one transition function and one threshold was selected for the financial stability analysis.

The financial stability function was estimated using a PSTR model in which the financial development index served as the transition variable. The estimated coefficients for both the linear and nonlinear components of the model are presented in Table 3.

Table 3. PSTR Estimation Results for the Financial Stability Model

Variable	Linear Coefficient	SE	*t*	*p*	Nonlinear Coefficient	SE	*t*	*p*
Constant	0.606596	0.052468	11.56128	0.0000	0.530693	0.136269	3.894459	0.0001
MC	0.105587	0.049589	2.129247	0.0345	0.112306	0.028029	4.006816	0.0001
BV	-0.022701	0.054364	-0.417576	0.6766	-0.265475	0.078286	-3.391090	0.0008
CT	0.083179	0.038798	2.143912	0.0331	0.110433	0.028554	3.867560	0.0001
FD	0.068757	0.014853	4.629124	0.0000	0.423817	0.183618	2.308149	0.0331
INF	-0.073317	0.058397	-1.255494	0.2107	-0.104390	0.041223	-2.532328	0.0121
SIZE	0.072988	0.040778	1.789885	0.0749	0.144645	0.037615	3.845384	0.0002
IQ	0.092592	0.039749	2.329430	0.0207	0.175549	0.071785	2.445475	0.0153
GROWTH	0.499005	0.268939	1.855461	0.0764	0.057005	0.019709	2.892297	0.0097
Threshold, c	—	—	—	—	0.217254	0.009450	22.98900	0.0000
Slope, γ	—	—	—	—	0.618469	0.056286	10.98804	0.0000

Adjusted $R^2 = .96$.

The results indicate that cryptocurrency market capitalization had a positive and statistically significant effect on financial stability in both components of the model. In the linear component, the coefficient for $MC$was $0.105587(p = .0345)$, whereas in the nonlinear component it increased to $0.112306(p = .0001)$. Similarly, cryptocurrency trading volume relative to GDP had a positive and statistically significant coefficient in both components, with coefficients of $0.083179(p = .0331)$ and $0.110433(p = .0001)$ in the linear and nonlinear components, respectively.

The positive effects of cryptocurrency market expansion on financial stability may be interpreted partly through innovation pressure and technological upgrading. Blockchain technology, even independently of Bitcoin, has encouraged the development of more efficient domestic settlement mechanisms, including instant payments, smart contracts, and distributed transaction infrastructures. Conventional banks adopting these technologies may therefore obtain higher operational efficiency. In this sense, cryptocurrency-market development may indirectly stimulate technological modernization within the conventional banking sector.

Another potential mechanism concerns portfolio diversification. From the consumer perspective, cryptocurrencies constitute an additional asset class whose return dynamics may differ from those of traditional financial assets. The availability of additional investment instruments may therefore contribute to diversification of household portfolios and, under certain conditions, reduce aggregate portfolio risk.

Cryptocurrencies may also provide alternative financial channels in economies characterized by high inflation, external restrictions, or limited access to conventional cross-border payment arrangements. In such environments, digital assets may temporarily provide alternative payment mechanisms and stores of value, potentially reducing some constraints arising from deficiencies in conventional financial channels.

The emergence of cryptocurrencies may additionally promote regulatory clarity and stronger supervisory discipline. The rapid expansion of digital assets has compelled financial regulators to identify previously unrecognized risks, update regulatory frameworks, and develop regulatory sandboxes. Regulatory weaknesses that might otherwise have remained unidentified can consequently become more visible and subject to institutional correction.

From the perspective of international financial institutions, International Monetary Fund financial stability assessments during 2021–2025 indicated that the direct cryptocurrency exposure of banks remained relatively limited during much of this period, at less than approximately 2% of total banking assets, while emphasizing that rapid expansion of fintech–crypto linkages in the absence of clear regulation could strengthen channels of financial contagion. Similarly, the Basel Committee and the Bank for International Settlements have emphasized the regulatory implications of stablecoins and other digital assets that increasingly exhibit deposit-like characteristics. In this perspective, the closer a digital asset becomes to functioning as money, the stronger the case becomes for applying comparable prudential and supervisory requirements.

Bitcoin volatility displayed a different pattern. Its coefficient was negative but statistically insignificant in the linear component ($\beta = -0.022701,\ p = .6766$), whereas it became negative and statistically significant in the nonlinear component ($\beta = -0.265475,\ p = .0008$). This result demonstrates that greater Bitcoin price volatility becomes detrimental to financial stability as the economy moves through the nonlinear transition. Increased cryptocurrency volatility may increase market risk, amplify uncertainty, and create additional channels through which shocks originating in digital-asset markets can be transmitted to the conventional financial system.

Financial development exerted a positive and statistically significant effect in both components. Its coefficient increased from $0.068757(p < .001)$ in the linear component to $0.423817(p = .0331)$ in the nonlinear component.

Bank size was positive but only marginally significant in the linear component ($\beta = 0.072988$, $p = .0749$), whereas it was positive and statistically significant in the nonlinear component ($\beta = 0.144645$, $p = .0002$). Institutional quality exerted a positive and significant effect in both components, with coefficients of $0.092592 (p = .0207)$ and $0.175549 (p = .0153)$, respectively. Economic growth was positive but marginally significant in the linear component ($\beta = 0.499005$, $p = .0764$) and positive and statistically significant in the nonlinear component ($\beta = 0.057005$, $p = .0097$). Inflation was statistically insignificant in the linear component ($\beta = -0.073317$, $p = .2107$), but became negative and statistically significant in the nonlinear component ($\beta = -0.104390$, $p = .0121$).

The comparison of coefficients across regimes is determined by the transition variable and its values because the value of the transition variable determines the transition function and, consequently, the prevailing regime. Financial development served as the transition variable in the estimated financial stability model, and its estimated threshold value was $c = 0.217254$, approximately 0.21. Thus, depending on the distance of the financial development index from this threshold, the model moves smoothly between the two limiting regimes. Comparison of the coefficients demonstrates that once financial development exceeds the threshold and the model moves from the predominantly linear toward the nonlinear regime, the responsiveness of financial stability to financial development rises substantially. In other words, as financial development improves and exceeds the estimated threshold, financial stability becomes increasingly responsive to changes in the level of financial development.

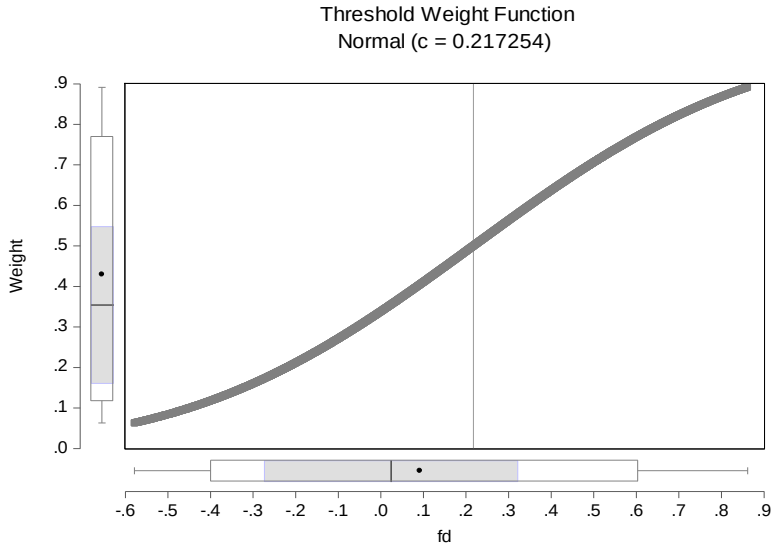


Figure 1. Relationship Between the Transition Function and the Financial Development Transition Variable

Diagnostic tests were subsequently conducted to examine the adequacy and statistical reliability of the estimated financial stability model. The Durbin–Watson statistic was 2.008, while the corresponding autocorrelation test produced an F-statistic of 1.385 and $p = .71$. These results indicate no statistically significant serial correlation among the disturbance terms. Therefore, the classical assumption of no autocorrelation was not violated, supporting the efficiency and minimum-variance properties of the estimators.

Homoskedasticity was assessed using the Breusch–Pagan–Godfrey test. The test statistic was 1.993, the F-statistic was 1.382, and the corresponding probability was .70. The results therefore provided no evidence of heteroskedasticity.

The stability of the estimated coefficients across regimes was also examined. Under the null hypothesis $b_1 = b_2 = b_3 = b_4 = 0$, the F-statistic was 0.852 ($p = .704$); for $b_1 = b_2 = b_3 = 0$, it was 0.742 ($p = .678$); for $b_1 = b_2 = 0$, it was 0.730 ($p = .552$); and for $b_1 = 0$, it was 0.895 ($p = .541$). Since none of these tests was statistically significant, the results indicate that the coefficients remained stable across regime transitions.

The same procedure was applied to the bank performance model. The null hypothesis again specified a linear relationship, whereas the alternatives represented logistic ($m = 1$) or exponential ($m = 2$) PSTR specifications. The Wald test produced an F-statistic of 5.385 ($p < .001$), the Fisher test yielded an F-statistic of 4.666 ($p < .001$), and the likelihood-ratio test yielded a statistic of 4.950 ($p < .001$). Therefore, the null hypothesis of linearity was rejected, confirming a nonlinear relationship between cryptocurrency-related variables and bank performance in the selected countries with conventional banking.

Following González et al. (2005) and Colletaz and Hurlin (2006), the null hypothesis of one transition function was tested against the alternative of at least two transition functions. Under the one-threshold specification ($M = 1$), the LM-Wald statistic was 1.008 ($p = .787$), the LM-Fisher statistic was 1.331 ($p = .601$), and the likelihood-ratio statistic was 1.725 ($p = .544$). Under the two-threshold specification ($M = 2$), the corresponding statistics were 1.952 ($p = .731$), 1.374 ($p = .742$), and 1.308 ($p = .514$). Hence, the null hypothesis was not rejected in either case. A single transition function was therefore sufficient to capture the nonlinear behavior of cryptocurrencies and bank performance.

After confirming nonlinearity and the adequacy of a single transition function, alternative one- and two-threshold PSTR specifications were estimated. Based on the residual sum of squares, Schwarz information criterion, and Akaike information criterion, the one-threshold specification was identified as the optimal model. Consequently, a PSTR model with one transition function and one threshold was selected for estimating bank performance.

A PSTR model with financial development as the transition variable was employed to estimate bank performance in the conventional banking sectors of the selected countries. The results are presented in Table 4.

Table 4. PSTR Estimation Results for the Bank Performance Model

Variable	Linear Coefficient	SE	*t*	*p*	Nonlinear Coefficient	SE	*t*	*p*
Constant	0.196692	0.095788	2.053411	0.0549	0.102195	0.043170	2.367280	0.0267
MC	0.123968	0.028846	4.297628	0.0004	0.228524	0.054462	4.196024	0.0005
BV	-0.474573	0.124633	-3.807772	0.0066	-0.242560	0.040182	-6.036585	0.0002
CT	0.112346	0.033569	3.346760	0.0036	0.137959	0.041832	3.297954	0.0040
FD	-0.116226	0.039950	-2.909323	0.0094	0.513400	0.157400	3.262762	0.0098
INF	-0.203325	0.054194	-3.751771	0.0045	-0.014838	0.006607	-2.245690	0.0378
SIZE	0.521203	0.272529	1.912466	0.0974	0.120704	0.060604	1.991677	0.0487
IQ	0.850933	0.336984	2.525142	0.0212	0.433451	0.159418	2.718959	0.0218
GROWTH	0.593920	0.289288	2.053044	0.0703	0.204690	0.089165	2.295631	0.0300
Threshold, c	—	—	—	—	0.964102	0.158623	6.077495	0.0000
Slope, γ	—	—	—	—	6.675325	2.934622	2.274678	0.0284

Adjusted $R^2 = .92$.

The results indicate that cryptocurrency market capitalization had a positive and statistically significant effect on bank performance in both regimes. Its coefficient was $0.123968 (p = .0004)$ in the linear component and increased to $0.228524 (p = .0005)$ in the nonlinear component. Similarly, cryptocurrency trading volume relative to GDP had a positive and statistically significant effect in both components, with coefficients of $0.112346 (p = .0036)$ and

$0.137959(p = .0040)$, respectively. Therefore, greater cryptocurrency market activity was associated with improved performance of conventional banks, conditional on the modeled level of financial development.

Several mechanisms may explain this positive association. First, cryptocurrencies create competitive pressure and accelerate innovation. As alternative payment channels, cryptocurrency-based systems can reduce transaction costs and settlement times. Such competitive pressure can encourage conventional banks to modernize legacy infrastructure, expand instant-payment services, introduce private or permissioned blockchain technologies, and improve user experience. The resulting mechanism may be summarized as competition →pressure on profit margins →stronger incentives for efficiency →improved average banking-sector efficiency. Consequently, conventional banks can reduce operating costs and improve service speed without necessarily developing entirely new infrastructures from the ground up.

Second, cryptocurrencies may contribute to the diversification of bank assets and the expansion of non-interest income. Banks and financial institutions can participate in the digital-asset ecosystem either through direct asset-related activities or by providing cryptocurrency-related services, including custody, transaction services, and advisory services. Fees generated from cryptocurrency exchange services, digital-asset custody, and related financial services can supplement non-interest income. Such revenue may provide an additional profitability buffer, particularly in environments characterized by low interest rates or compressed interest margins.

Third, distributed ledger technology may improve transparency, reduce fraud, and strengthen risk management. Blockchain-based systems allow more precise transaction traceability and matching. In applications such as letters of credit, international transfers, and financial logistics, the use of distributed ledgers can reduce human error and certain forms of fraud. These improvements may reduce operational risk costs and enhance the reliability of banks' balance sheets and transaction records.

Fourth, exposure to cryptocurrency markets can contribute to the clarification and evolution of the regulatory framework. The expansion of digital assets forces central banks and supervisory institutions to develop more precise rules governing emerging forms of financial activity. Over the longer term, clearer regulatory frameworks can reduce legal uncertainty faced by banks, improve decision-making, lower compliance-related uncertainty, and facilitate more secure investment. This represents the opposite of the regulatory-uncertainty effect observed when rules governing digital assets remain ambiguous; as frameworks become clearer, the net institutional effect may become more favorable.

Fifth, distributed ledger technologies may improve payment infrastructure and reduce dependence on intermediaries. Conventional banks incorporating distributed ledger technology into their payment infrastructure may reduce interbank transaction fees and substantially shorten the processing time of cross-border transactions, potentially reducing settlement from several days to minutes in some applications. Such improvements could increase efficiency in international payments, an area in which traditional banking has historically faced comparatively high transaction costs and lengthy settlement procedures.

Bitcoin volatility, however, exerted a negative and statistically significant effect on bank performance in both components of the model. Its coefficient was $-0.474573(p = .0066)$ in the linear component and $-0.242560(p = .0002)$ in the nonlinear component. Thus, although expansion in cryptocurrency market size and trading activity was associated with improved bank performance, increased volatility in the principal cryptocurrency market adversely affected banking performance. This finding suggests that the benefits associated with digital-asset activity coexist with substantial market-risk exposure and uncertainty arising from cryptocurrency price fluctuations.

The effect of financial development changed markedly between the two components. In the linear component, financial development had a negative and statistically significant coefficient of $-0.116226(p = .0094)$, whereas in the nonlinear component it became positive and statistically significant, with a coefficient of $0.513400(p = .0098)$. This reversal indicates that the effect of financial development on bank performance depends critically on whether the financial system has moved beyond the estimated threshold. At relatively lower levels of financial development, stronger competition and changes in financial intermediation may exert downward pressure on conventional-bank profitability. Once financial development reaches a sufficiently high level, however, improvements in financial infrastructure, technological capabilities, and market efficiency may transform these competitive pressures into opportunities for increased efficiency and revenue generation.

Inflation had a negative and statistically significant effect on bank performance in both components. Its coefficient was $-0.203325(p = .0045)$ in the linear component and $-0.014838(p = .0378)$ in the nonlinear component. Bank size was positive but only marginally significant in the linear component ($\beta = 0.521203,\ p = .0974$), whereas it became positive and statistically significant in the nonlinear component ($\beta = 0.120704,\ p = .0487$). Institutional quality had a positive and statistically significant effect in both components, with coefficients of $0.850933(p = .0212)$ and $0.433451(p = .0218)$. Economic growth was positive but marginally significant in the linear component ($\beta = 0.593920, p = .0703$) and positive and statistically significant in the nonlinear component ($\beta = 0.204690, p = .0300$).

The regime comparison is determined by the financial development transition variable. The estimated threshold was $c = 0.964102$. Accordingly, the PSTR specification shifts smoothly between the two limiting regimes according to the position of the financial development index relative to this threshold. Comparison of the estimated coefficients demonstrates that once financial development moves beyond the threshold of 0.964102, corresponding to movement from the predominantly linear toward the nonlinear component, the responsiveness of bank performance to financial development increases markedly. This finding indicates that banking-sector policymakers operating in more financially developed environments may have greater capacity to respond to technological and market changes, support bank performance, and mitigate potential declines in profitability.

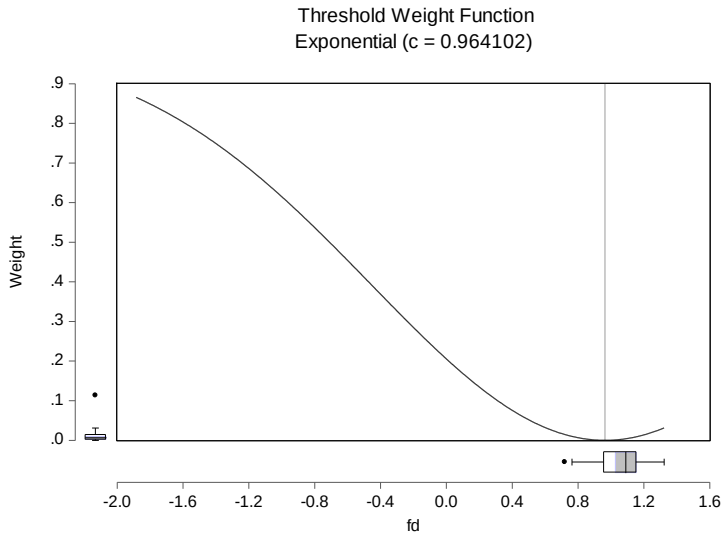


Figure 2. Relationship Between the Transition Function and the Financial Development Transition Variable

Diagnostic tests were also conducted for the bank performance specification. The Durbin–Watson statistic was 2.010, with an associated F-statistic of 1.770 and $p = .40$. These results indicate that the disturbance terms were

not serially correlated. Accordingly, the classical assumption of no autocorrelation was not violated, and the estimators retained the required efficiency properties.

The Breusch–Pagan–Godfrey test was used to assess heteroskedasticity. The test statistic was 1.730, accompanied by an F-statistic of 0.683 and $p = .554$. Consequently, there was no statistically significant evidence of heteroskedasticity in the bank performance model.

Coefficient stability across the two regimes was also evaluated. For the null hypothesis $b_1 = b_2 = b_3 = b_4 = 0$, the F-statistic was 1.424 ($p = .540$); for $b_1 = b_2 = b_3 = 0$, it was 1.007 ($p = .401$); for $b_1 = b_2 = 0$, it was 1.178 ($p = .534$); and for $b_1 = 0$, it was 1.227 ($p = .642$). None of these statistics was significant, indicating that the estimated coefficients remained stable as the model moved between regimes.

For clarity, the principal diagnostic findings for both estimated PSTR models are summarized in Table 5.

Table 5. Summary of Diagnostic Tests for the Estimated PSTR Models

Diagnostic Test	Financial Stability Model	*p*-value	Bank Performance Model	*p*-value	Conclusion
Durbin–Watson statistic	2.008	—	2.010	—	No evidence of autocorrelation
Autocorrelation, F	1.385	0.710	1.770	0.400	Null not rejected
Breusch–Pagan–Godfrey statistic	1.993	—	1.730	—	No evidence of heteroskedasticity
Heteroskedasticity, F	1.382	0.700	0.683	0.554	Null not rejected
Stability: $b_1 = b_2 = b_3 = b_4 = 0$	0.852	0.704	1.424	0.540	Coefficients stable
Stability: $b_1 = b_2 = b_3 = 0$	0.742	0.678	1.007	0.401	Coefficients stable
Stability: $b_1 = b_2 = 0$	0.730	0.552	1.178	0.534	Coefficients stable
Stability: $b_1 = 0$	0.895	0.541	1.227	0.642	Coefficients stable

To provide an integrated comparison of the nonlinear specifications, the principal model-selection and transition parameters are summarized in Table 6. Both models rejected linearity, supported the adequacy of a single transition function, and favored a one-threshold PSTR specification. Nevertheless, the estimated transition dynamics differed substantially. The financial stability model had a considerably lower threshold ($c = 0.217254$) and a relatively gradual transition ($\gamma = 0.618469$), whereas the bank performance model had a substantially higher threshold ($c = 0.964102$) and a much steeper transition ($\gamma = 6.675325$).

Table 6. Summary of PSTR Specification and Transition Parameters

Characteristic	Financial Stability Model	Bank Performance Model
Transition variable	Financial development	Financial development
Linearity rejected	Yes	Yes
Selected transition functions	1	1
Selected thresholds	1	1
Threshold parameter, c	0.217254	0.964102
Slope parameter, γ	0.618469	6.675325
Adjusted R^2	0.96	0.92
Preferred specification	One-function, one-threshold PSTR	One-function, one-threshold PSTR

Overall, the findings demonstrate that the relationship between cryptocurrency-market development and conventional banking is intrinsically nonlinear and is conditioned by the level of financial development. Cryptocurrency market capitalization and cryptocurrency trading volume relative to GDP were positively associated with both financial stability and bank performance, whereas Bitcoin volatility generally exerted adverse effects, particularly in the nonlinear financial stability regime and in both components of the bank performance model. Financial development itself played a central threshold role: once it crossed the estimated regime-specific threshold,

the magnitude and, in the case of bank performance, even the direction of its association changed substantially. The diagnostic results further indicated that the estimated models were not affected by statistically significant autocorrelation or heteroskedasticity and that their coefficients remained stable across regimes, supporting the statistical adequacy of the estimated PSTR specifications.

Discussion and Conclusion

The present study examined the nonlinear effects of cryptocurrency market capitalization, Bitcoin price volatility, and cryptocurrency trading volume relative to GDP on financial stability and bank performance in the conventional banking sectors of selected Islamic countries with dual banking systems during 2013–2024. The findings confirmed that the relationship between cryptocurrency-market development and conventional banking is nonlinear and depends substantially on the level of financial development. The rejection of the linearity hypothesis for both the financial stability and bank performance models demonstrates that the effects of cryptocurrencies cannot be adequately represented by assuming constant marginal effects across different financial environments. This result is consistent with the growing body of evidence emphasizing the time-varying, asymmetric, and regime-dependent nature of interactions between cryptocurrency and conventional financial markets. For example, Huang reported that the causal relationship between cryptocurrencies and conventional financial markets changes over time and depends on prevailing market conditions (7), while Gu et al. demonstrated that spillover effects between cryptocurrency and regulated financial markets differ significantly across quantiles and market states (13). Similarly, Zhou and Gu showed that the network structure of cryptocurrency markets and the transmission of volatility are inherently time-varying (10). The nonlinear findings of the present study therefore reinforce the argument that the implications of cryptocurrency development for conventional banking should be evaluated within a regime-dependent framework rather than through a purely linear specification.

The results of the financial stability model revealed that cryptocurrency market capitalization had a positive and statistically significant effect on financial stability in both the linear and nonlinear components. The estimated coefficient increased slightly from (0.105587) in the linear component to (0.112306) in the nonlinear component, suggesting that the expansion of the cryptocurrency market is associated with stronger financial stability after accounting for nonlinear adjustment. This finding may initially appear counterintuitive because cryptocurrencies are frequently characterized as speculative and volatile assets. However, cryptocurrency-market expansion can also stimulate technological upgrading, payment innovation, competition, and the diversification of financial services. Nejad Moghadam emphasized the role of cryptocurrencies and digital currencies in advancing monetary technologies and transforming payment and financial infrastructures (1). Varmziari et al. likewise argued that strategic development of cryptocurrency-related activities within national banking systems can create opportunities for technological modernization and stronger competitive capacity (18). In this respect, expansion of the cryptocurrency ecosystem may indirectly strengthen conventional banks by forcing them to modernize settlement systems, digital platforms, and risk-management technologies. Sabeghat also showed that digital currencies can alter banking models and monetary policy mechanisms, indicating that their effects extend beyond speculative trading and can influence the operational structure of financial intermediation (21).

Cryptocurrency trading volume relative to GDP also exerted a positive and statistically significant effect on financial stability in both regimes. The coefficient increased from (0.083179) in the linear component to (0.110433) in the nonlinear component. This finding suggests that greater cryptocurrency-market activity relative to the size of

the economy does not necessarily undermine conventional banking stability and may, under appropriate institutional conditions, complement the broader financial system. One explanation is that increasing digital-asset activity creates demand for banking services related to payment settlement, custody, conversion, compliance, and financial technology. The growing legal recognition of cryptocurrencies as instruments with economic value may further facilitate their interaction with formal financial institutions. Amiri and Kazemi discussed the evolving validity of digital currencies as media of exchange and means of payment, indicating that their integration with established financial transactions is progressively becoming a legal and economic reality (3). Alipour and Jannesar Malakouti Bijarpas similarly considered the feasibility of using cryptocurrencies as collateral in banking relationships, illustrating possible channels through which digital assets may become integrated into conventional intermediation (19). Such integration may enable banks to capture new fee-based activities rather than simply losing customers or liquidity to decentralized markets.

In contrast, Bitcoin price volatility had a negative but statistically insignificant effect on financial stability in the linear regime and a negative and statistically significant effect in the nonlinear regime, with the coefficient reaching (-0.265475). This finding indicates that once the financial system crosses the relevant transition range, increased Bitcoin volatility becomes a meaningful source of financial instability. The result is consistent with studies showing that cryptocurrency volatility can generate substantial risk transmission and uncertainty. Harasheh and Bouteska documented the distinctive stochastic volatility characteristics of cryptocurrencies and emphasized the substantial uncertainty embedded in their price dynamics (9). M'Bakob provided both theoretical and empirical evidence that attention cycles among cryptocurrency investors can generate spillover effects affecting broader financial-market stability (17). Ali et al. similarly identified return and volatility spillovers between cryptocurrency markets and major conventional markets (16). The result is also in line with Kazouz and Yousfi, who demonstrated asymmetric risk spillovers between cryptocurrency segments under different geopolitical and financial risk conditions (14). These studies support the present finding that cryptocurrency-market size and activity can generate economic opportunities, while extreme volatility remains a distinct destabilizing channel.

The results further showed that financial development had a positive and statistically significant effect on financial stability in both regimes, with its coefficient increasing substantially from (0.068757) to (0.423817). The estimated financial-development threshold was (c=0.217254), while the slope parameter was (\gamma=0.618469). These estimates indicate a relatively gradual transition between regimes and demonstrate that financial stability becomes increasingly responsive to financial development after the threshold is crossed. This result highlights the absorptive capacity of more developed financial systems. Financially developed economies typically possess stronger regulatory structures, more sophisticated financial institutions, deeper capital markets, and improved risk-management systems, which may allow them to incorporate cryptocurrency-related innovation without experiencing equivalent increases in systemic vulnerability. This interpretation is compatible with Afkaneh's analysis of financial fragility, which emphasizes that the capacity to manage crises and maintain economic stability depends critically on the strength and development of financial institutions (6). It is also consistent with Khan et al., who showed that institutional conditions and governance structures significantly influence bank risk-taking in dual banking systems (27).

Institutional quality was positively and significantly related to financial stability in both regimes, while bank size and economic growth became statistically significant in the nonlinear component. These findings suggest that larger banking institutions, stronger institutional environments, and more favorable macroeconomic conditions can

reinforce the capacity of conventional banks to absorb digital-market shocks. Higher institutional quality likely improves regulatory enforcement, transparency, supervision, and legal predictability, all of which reduce uncertainty surrounding cryptocurrency exposure. This interpretation is particularly relevant because the legal classification and regulatory treatment of cryptocurrencies remain evolving. Ghanoun emphasized the importance of economic law in structuring cryptocurrency markets and defining their institutional boundaries (2), while Khosravi and Ghari Rostami demonstrated that cryptocurrency transactions require careful legal and jurisprudential treatment to establish predictable rights and obligations (5). Kharratha et al. likewise highlighted conceptual challenges surrounding the legal treatment of cryptocurrencies as currencies (4). Consequently, stronger institutional quality can facilitate clearer regulatory responses and reduce the destabilizing effects associated with legal ambiguity.

Inflation did not have a statistically significant effect on financial stability in the linear component but became negative and significant in the nonlinear regime. This result suggests that inflation becomes more detrimental to bank stability under conditions in which financial development and cryptocurrency-market integration are more advanced. Higher inflation can weaken the real value of assets, increase funding uncertainty, alter deposit behavior, and intensify portfolio shifts toward alternative assets. In environments where digital assets are readily accessible, inflation may also encourage households and firms to substitute away from domestic-currency instruments toward cryptocurrencies, creating additional liquidity-management pressures for banks. The finding is broadly compatible with the argument that cryptocurrencies may serve as alternative stores of value or transaction instruments in unstable monetary environments. Sakouti et al. showed that digital currencies may have broader macroeconomic consequences, including effects on economic growth and financial activity (26), while Naseri Taheri and Divandari emphasized that cryptocurrency policymaking must account for interactions with trade, monetary management, and broader economic policy (22).

Regarding bank performance, cryptocurrency market capitalization exerted a positive and statistically significant effect in both regimes, with its coefficient increasing from (0.123968) to (0.228524). Cryptocurrency trading volume relative to GDP also had a positive and significant effect, rising from (0.112346) to (0.137959). These findings suggest that expansion of cryptocurrency activity may improve conventional-bank profitability when banks are able to adapt their business models and capture new sources of revenue. Digital-asset markets can create opportunities in custody, transaction processing, compliance services, advisory activities, and technology provision. The feasibility of cryptocurrencies being incorporated into collateral arrangements also indicates that digital assets may gradually become linked to conventional credit markets (19). More broadly, Gadzinski and Liuzzi showed that lending behavior in decentralized finance is responsive to liquidation mechanisms and market structure, illustrating how cryptocurrency-based financial activities can increasingly interact with credit allocation (20). As traditional institutions develop capabilities to participate in these markets, cryptocurrency expansion may contribute to the diversification of non-interest income and improve operational efficiency.

The positive association between cryptocurrency activity and bank performance can also be interpreted through competition-induced innovation. Conventional banks facing competition from decentralized payment platforms and digital financial services may respond by improving user experience, reducing transaction costs, implementing faster settlement systems, and investing in distributed ledger technologies. Such adjustments can improve efficiency and protect profitability over time. The finding is consistent with Sabeghat's conclusion that digital currencies can lead to changes in banking business models (21) and with Varmziari et al., who emphasized strategic planning as a prerequisite for the successful integration of cryptocurrencies into banking systems (18). Moreover,

growing consumer trust in cryptocurrency-based transactions can accelerate demand for digital financial services. Lee found that cryptocurrency adoption and trust are strongly influenced by market volatility and environmental conditions (29), indicating that banks capable of providing trustworthy, regulated interfaces for digital assets may be able to convert changing consumer preferences into new business opportunities.

Bitcoin volatility had a negative and statistically significant effect on bank performance in both regimes. The coefficient was (-0.474573) in the linear regime and (-0.242560) in the nonlinear regime. Thus, despite the positive effects associated with cryptocurrency-market scale and trading intensity, price instability remains harmful to conventional-bank performance. Greater volatility can increase risk-management expenses, reduce the value of cryptocurrency-related assets, generate customer losses, create liquidity uncertainty, and increase the cost of providing digital-asset services. Alari and Nikseresht demonstrated the importance of improving cryptocurrency volatility forecasting by incorporating investor sentiment (8), underscoring the central role of unpredictability in digital-asset markets. Harasheh and Bouteska similarly demonstrated the complexity of cryptocurrency volatility processes (9). Popova et al. further showed that geopolitical events can substantially alter cryptocurrency-market behavior and safe-haven properties (15). Together, these studies support the conclusion that the performance benefits associated with cryptocurrency activity are conditional on banks' ability to manage substantial market uncertainty.

One of the most important findings of the bank performance model concerns financial development. Its coefficient was negative and statistically significant in the linear regime ((\beta=-0.116226)) but became positive and statistically significant in the nonlinear regime ((\beta=0.513400)). The threshold was estimated at (c=0.964102), with a relatively high slope parameter of (\gamma=6.675325), indicating a much sharper transition between regimes than in the financial stability model. This sign reversal suggests that at lower levels of financial development, increased development may initially intensify competition, compress conventional-bank margins, and facilitate substitution toward alternative financial channels. Once the financial system becomes sufficiently developed, however, technological capacity, market depth, supervisory sophistication, and institutional readiness may allow banks to transform these pressures into efficiency and revenue gains. This result therefore provides strong evidence that the relationship between cryptocurrency integration and bank performance is conditional on the maturity of the broader financial system.

Institutional quality had a positive and statistically significant effect on bank performance in both regimes, whereas bank size and economic growth became significant in the nonlinear component. These findings indicate that financially stronger and institutionally better-governed environments enable conventional banks to exploit digital innovation more effectively. Regulatory evolution appears especially important because the development of central bank digital currencies and cryptocurrency regulations increasingly shapes expectations about the future structure of payments and financial intermediation. Ahmadrahban et al. showed that central bank digital currency news can affect financial-market behavior (24), while Akhtarzadeh Zavareh identified important challenges in the implementation of central bank digital currencies (23). Eftekhari and Mostajeran further demonstrated that the financial-stability implications of central bank digital currencies depend on their design and interaction with the banking sector (25). These studies reinforce the present conclusion that institutional and regulatory capacity determines whether digital-financial innovation becomes a source of improved banking performance or increased vulnerability.

Overall, the findings demonstrate a clear distinction between cryptocurrency-market development and cryptocurrency-market volatility. Market capitalization and trading activity were positively associated with both financial stability and bank performance, whereas Bitcoin volatility had adverse effects. This distinction helps reconcile apparently contradictory views in the literature. Cryptocurrencies may simultaneously create opportunities for innovation and diversification while generating new channels of risk transmission. Goh and Jeon's analysis of investor behavior and mispricing highlights the importance of informed market participation in correcting price distortions (12), while Ijaz et al. demonstrate more generally that dynamic connectedness across asset classes has important implications for diversification and risk management (28). The results of the present study suggest that similar principles apply to cryptocurrency exposure: benefits depend on market structure and diversification opportunities, whereas unmanaged volatility can undermine both stability and profitability. Accordingly, cryptocurrency expansion should not be interpreted as inherently stabilizing or destabilizing; its ultimate effect is conditional on volatility, institutional quality, financial development, and the capacity of conventional banks to adapt.

This study has several limitations that should be considered when interpreting the findings. First, the analysis is restricted to the conventional banking sectors of six Islamic countries with dual banking systems—Turkey, Pakistan, Azerbaijan, Malaysia, Jordan, and Algeria—during the 2013–2024 period; therefore, the results may not be directly generalizable to countries with fully conventional, fully Islamic, or substantially different financial architectures. Second, cryptocurrency-market activity was represented through market capitalization, Bitcoin volatility, and cryptocurrency trading volume relative to GDP, whereas other relevant dimensions such as stablecoin adoption, decentralized finance participation, institutional cryptocurrency holdings, bank-specific digital-asset exposure, and cross-border crypto flows were not explicitly incorporated. Third, the use of annual data may conceal high-frequency dynamics that are particularly important in cryptocurrency markets, where volatility and spillovers can emerge within days or even hours. Fourth, although the PSTR framework captures nonlinear regime changes, it does not necessarily identify all potential causal mechanisms underlying the estimated relationships. Finally, differences in national regulatory frameworks, cryptocurrency adoption rates, market depth, and bank-specific technological capabilities may not be fully represented by the included control variables.

Future studies should extend the analysis by incorporating a broader sample of countries and comparing conventional, Islamic, and dual banking systems to determine whether the estimated nonlinear effects differ across banking architectures. Researchers may also use quarterly, monthly, or daily data to capture short-term volatility transmission and dynamic responses more accurately. Additional cryptocurrency indicators, including stablecoin capitalization, decentralized finance activity, institutional ownership, exchange flows, blockchain transaction intensity, and bank-specific digital-asset exposure, could provide a more comprehensive assessment of digital-financial integration. Future work could also distinguish among different cryptocurrency categories rather than relying heavily on Bitcoin as the primary volatility indicator. Methodologically, dynamic panel threshold models, quantile regressions, nonlinear ARDL models, dynamic connectedness frameworks, and regime-switching models could be employed to test the robustness of the findings. Further studies should also investigate whether regulatory quality, technological readiness, financial inclusion, monetary policy credibility, and cybersecurity capacity moderate the relationship between cryptocurrency development and banking outcomes.

Banking regulators and conventional financial institutions should distinguish between the growth of cryptocurrency-related financial activity and the risks associated with excessive price volatility. Banks can benefit from digital-asset expansion by investing in secure custody services, faster payment systems, blockchain-based

settlement infrastructure, and appropriately regulated fee-generating digital services, while simultaneously maintaining conservative exposure limits to highly volatile assets. Policymakers should strengthen institutional quality, improve supervisory coordination, establish clear legal classifications for digital assets, and develop transparent prudential requirements for cryptocurrency-related banking activities. Particular attention should be given to financial-development thresholds because the findings indicate that banks operating in less-developed financial systems may experience different effects from those operating in more advanced environments. Regulators should therefore avoid uniform approaches and instead calibrate cryptocurrency policies to the technological capacity, financial depth, risk-management sophistication, and institutional quality of their domestic banking systems.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adheried in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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