“Bank deposits and non-oil economic growth in Azerbaijan: Evidence from linear and nonlinear Granger causality”

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ARTICLE INFO	Ramil Hasanov, Zeynab Giyasova, Juan A. Parrilla González, Aynur Jabbarova, Naila Akhundova and Laman Ahmadova (2026). Bank deposits and non-oil economic growth in Azerbaijan: Evidence from linear and nonlinear Granger causality. *Banks and Bank Systems*, *21*(4), 129–145. doi:10.21511/bbs.21(4).2026.09
DOI	http://dx.doi.org/10.21511/bbs.21(4).2026.09
RELEASED ON	Tuesday, 03 November 2026
RECEIVED ON	Sunday, 02 August 2026
ACCEPTED ON	Friday, 16 October 2026

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JOURNAL	"Banks and Bank Systems"
ISSN PRINT	1816-7403
ISSN ONLINE	1991-7074
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
34	6	11

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BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine

www.businessperspectives.org

Type of the article: Research Article

Received on: 2nd of August, 2026
Accepted on: 16th of October, 2026
Published on: 3rd of November, 2026

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Conflict of interest statement:
Author(s) reported no conflict of interest

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BANK DEPOSITS AND NON-OIL ECONOMIC GROWTH IN AZERBAIJAN: EVIDENCE FROM LINEAR AND NONLINEAR GRANGER CAUSALITY

Abstract

This study examines the predictive relationship between real non-oil economic growth and household bank deposit growth in Azerbaijan using annual data for 2000–2024. Real non-oil GDP and individual bank deposits are measured at constant 2010 prices and transformed into annual logarithmic growth rates. The empirical analysis combines conventional linear Granger causality testing with a nonlinear Kernel Granger causality approach based on radial basis function kernel ridge regression. Nonlinear predictive performance is assessed through expanding-window rolling-origin cross-validation and a circular-shift permutation test. The results indicate a modest improvement in predictive accuracy when nonlinear information is incorporated, with mean squared error declining from 402.41 to 376.16, corresponding to a 3.32% reduction in root mean squared error. Nevertheless, the Kernel Granger statistic is statistically insignificant (KGC = 0.067, p = 0.416), providing no robust evidence of nonlinear predictive causality. Conventional linear Granger testing initially suggests unidirectional causality from non-oil GDP growth to household deposit growth (F = 5.305, p = 0.032), with no evidence of reverse causality. However, introducing a 2015–2016 crisis pulse dummy substantially reduces the lagged GDP growth coefficient from 1.818 to 0.689 and eliminates its statistical significance, while the crisis indicator remains highly significant. These findings suggest that the apparent linear relationship is largely driven by the 2015–2016 macro-financial shock rather than a stable underlying mechanism. Overall, the evidence does not support a robust linear or nonlinear predictive relationship between non-oil economic growth and household deposit growth in Azerbaijan.

Keywords bank deposits, non-oil economic growth, kernel Granger causality, linear Granger causality, kernel ridge regression, Azerbaijan

JEL Classification C53, C58, E21, G21, O47

INTRODUCTION

Household bank deposits constitute one of the principal channels through which financial resources are transferred from the real economy to the banking system. Financial intermediation theory suggests that economic expansion increases household income and savings, enabling commercial banks to mobilize larger deposit volumes that subsequently finance investment and productive activities (Diamond, 1984; Levine, 2005). In this context, sustained economic growth is expected to strengthen banks' deposit base by enhancing both household saving capacity and confidence in the financial system.

Recent advances in the finance–growth literature have further emphasized that bank deposits are not merely an outcome of economic expansion but also an important driver of long-term economic development. Improvements in financial outreach, digital banking, and insti-

tutional quality have increased households' willingness to channel financial resources into the banking sector, thereby improving financial intermediation and expanding the funding available for investment and productive activities (Peng et al., 2025). Moreover, deposits represent the primary source of banks' funding liquidity, allowing financial institutions to sustain lending and investment even during periods of limited external financing (Thakor & Yu, 2024). Together, these theoretical and empirical perspectives highlight the strategic role of household deposits in strengthening the link between real economic activity and financial sector development.

The importance of this relationship is particularly evident in Azerbaijan, where economic policy has increasingly focused on diversifying growth beyond the hydrocarbon sector. Over the past two decades, the country's non-oil economy has expanded substantially, with non-oil gross domestic product increasing from AZN 3.1 billion in 2000 to AZN 75.7 billion in 2024, reflecting significant progress in economic diversification (CEIC Data, 2026). This transformation has strengthened the contribution of the non-oil sector to national economic performance while raising an important policy question as to whether sustained non-oil economic growth has also translated into stronger household savings and greater deposit accumulation in the banking system.

The banking sector provides a favorable environment for household savings through relatively attractive deposit returns. In Azerbaijan, deposit interest rates generally range between 8-10% for maturities of 6-12 months and may reach approximately 12% for deposits with maturities of 12-24 months, providing households with incentives to place savings in commercial banks (Banker, 2026). At the same time, deposits remain the dominant funding source for the banking sector. As of 2026, deposits accounted for 74.6% of total banking liabilities, amounting to AZN 39.7 billion, of which 56.1% belonged to legal entities and 43.9% to households, highlighting the significant contribution of household savings to banking sector liquidity (CBAR, 2026). Furthermore, the Azerbaijani banking system held approximately AZN 4.6 billion in excess liquidity by the end of June 2026, while interest rates on newly accepted household and corporate deposits declined compared with the previous year, reflecting changing funding conditions and evolving dynamics within the domestic deposit market (FED, 2026).

Understanding whether the expansion of the non-oil economy has contributed to household deposit accumulation is important for evaluating the effectiveness of Azerbaijan's economic diversification strategy and the role of the banking sector in mobilizing domestic financial resources. Clarifying this relationship may also provide useful implications for policies aimed at strengthening financial intermediation and promoting sustainable non-oil economic development.

1. LITERATURE REVIEW

Previous studies have consistently highlighted the close relationship between bank deposits and economic growth, although the underlying transmission mechanisms have been examined from different perspectives. Peng et al. (2025) argued that improvements in financial outreach encourage households to transfer idle cash into the banking system, thereby expanding bank deposits and indirectly supporting economic growth through stronger financial intermediation. Their findings suggest that deposits serve not only as a source of bank funding but also as an important channel linking financial development with real economic activity. The determinants and economic implications of deposit growth have also received considerable attention. Yakubu and Abokor (2020) found that economic growth was one of the key drivers of deposit mobilization in Turkey, alongside banking-sector and macroeconomic factors, indicating that improvements in economic conditions stimulate deposit accumulation over the long run. Similarly, Han and Melecky (2013) showed that broader access to bank deposits enhanced the resilience of banks during periods of financial stress by creating a more diversified and stable deposit base, emphasizing the importance of household deposits for financial stability. Evidence from developing economies further supports the existence of a strong interaction be-

http://dx.doi.org/10.21511/bbs.21(4).2026.09

tween banking activity and economic performance. Consistent evidence has also been documented across different economic settings, suggesting that financial development, institutional quality, and deposit mobilization play complementary roles in promoting economic growth and strengthening banking sector performance (Ayadi et al., 2015; Nguyen, 2022; Naula et al., 2025). These studies indicate that household bank deposits play a central role in supporting financial intermediation, economic growth, and banking sector stability, while also highlighting the importance of examining this relationship in country-specific contexts such as Azerbaijan.

The relationship between banking sector development and economic growth has also been examined from the perspective of financial intermediation and resource allocation. Akpan et al. (2017) found that several indicators of financial sector development, including total bank deposits, exhibited a bidirectional causal relationship with economic growth in Nigeria, highlighting the mutually reinforcing nature of financial deepening and real economic expansion. Focusing on an oil-exporting economy, Saif-Alyousfi et al. (2018) demonstrated that fluctuations in oil and gas prices significantly influenced bank deposit growth in Qatar, although the transmission mechanism differed between conventional and Islamic banks, reflecting the importance of macroeconomic and institutional conditions. Similarly, Alzyadat (2021) reported that bank credit played a significant role in promoting non-oil economic growth in Saudi Arabia, suggesting that financial intermediation remains a key driver of economic diversification in resource-dependent economies. More recent evidence has reinforced these conclusions by showing that financial development, credit availability, money supply, financial inclusion, and export-related financial support continue to play important roles in strengthening economic performance, export competitiveness, and sustainable development across developing and emerging economies (Mwakalila et al., 2025; Wahab, 2026; Saidi et al., 2026).

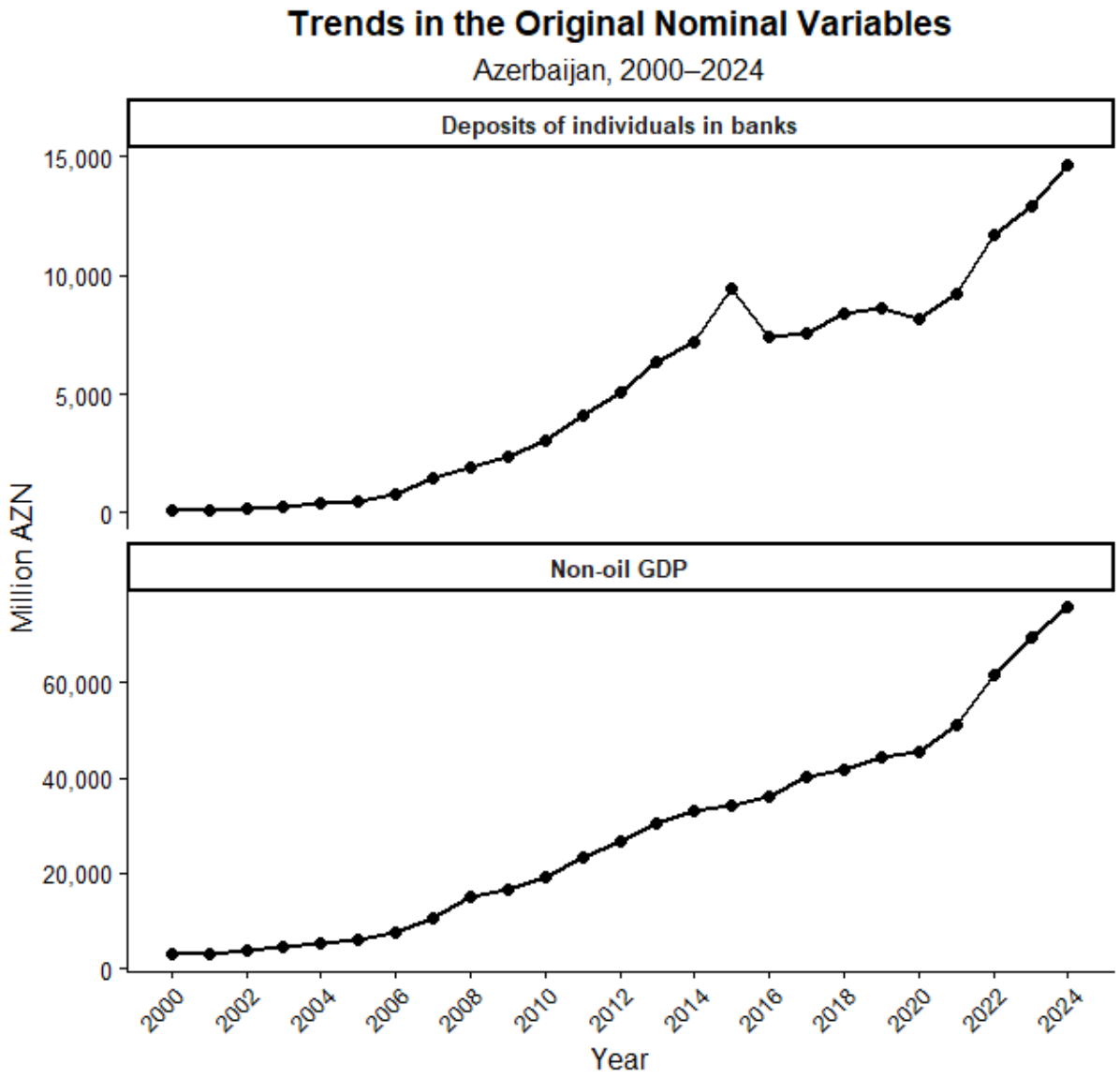
Empirical evidence for Azerbaijan has similarly highlighted the close interaction between financial sector development and the performance of the non-oil economy. Hasanov and Huseynov (2013) found that bank credit exerted a significant positive effect on non-oil tradable sector output in both the short and long run, emphasizing the importance of financial intermediation in supporting economic diversification. More recently, Seyfullayev (2023) examined the dynamic relationship between financial development and non-oil economic growth and reported the absence of long-run causality, although short-run unidirectional causality was identified from bank lending to non-oil growth. The study further suggested that strengthening deposit mobilization, expanding money supply, and increasing credit to the non-oil sector could enhance sustainable economic growth. Recent Azerbaijan-focused research has consistently highlighted the contribution of banking, finance, and public financial management to non-oil sector development and sustainable economic growth, reinforcing the importance of financial sector development in advancing the country's long-term diversification objectives (Yusifov, 2020; Niftiyev, 2025; Abdullayev et al., 2025). Collectively, all these findings underscore the importance of the banking sector in facilitating Azerbaijan's diversification process, while also indicating that the finance–growth relationship remains complex and warrants further empirical investigation using alternative methodological approaches.

Despite the growing body of research on financial development and economic growth, limited attention has been paid to whether real non-oil economic growth contains predictive information for household bank deposit growth, particularly in the context of Azerbaijan. This study addresses this gap by examining the predictive relationship between real non-oil GDP growth and household deposit growth, with the central hypothesis that past non-oil economic growth does not Granger-cause household deposit growth, while the alternative hypothesis assumes that non-oil GDP growth provides additional predictive information beyond the historical dynamics of bank deposits themselves.

2. MATERIAL AND METHODS

2.1. Data formation

This study employs annual data for Azerbaijan covering the period 2000–2024. The original dataset comprises Non-oil Gross Domestic Product (GDP) measured at current prices (million AZN) and Deposits of Individuals in Banks, reported



Note: Non-oil GDP is measured at current prices; deposits are reported as end-of-year balances.

Figure 1. Trends in the original nominal variables

as end-of-year balances (million AZN). The primary data were obtained from the State Statistical Committee of the Republic of Azerbaijan (SSCRA, 2026) and cross-validated with the corresponding macroeconomic indicators available in the World Development Indicators database of the World Bank (WB, 2026) to ensure consistency and reliability.

Because both variables are expressed in nominal terms, they are subject to inflationary distortions over time. To obtain inflation-adjusted measures that better reflect real economic dynamics, the original series were deflated using the Consumer Price Index (CPI, 2010 = 100). The use of CPI as the deflator for non-oil GDP reflects data availability and provides a common inflation-adjustment basis across the two monetary series. Nevertheless, CPI measures changes in consumer prices rather than the implicit price structure of non-oil output and therefore does not constitute an ideal sector-specific GDP deflator. The resulting real non-oil GDP measure should consequently be interpreted as a CPI-adjusted approximation of real economic activity, and this measurement limitation is acknowledged when interpreting the empirical results.

http://dx.doi.org/10.21511/bbs.21(4).2026.09

The resulting real variables – Real Non-oil Gross Domestic Product and Real Deposits of Individuals in Banks – are expressed in constant 2010 prices (million AZN). Subsequently, both series were transformed into natural logarithms and first differences to derive annual growth rates, which were employed in the linear Granger causality and Kernel Granger causality analyses. This transformation reduces the influence of price-level changes and facilitates the examination of the dynamic predictive relationship between real non-oil economic activity and household bank deposits.

Figure 1 illustrates a pronounced upward trend in both non-oil GDP and deposits of individuals in banks over the 2000–2024 period, reflecting the substantial expansion of Azerbaijan's non-oil economy alongside the deepening of the banking sector. While both variables exhibit sustained long-run growth, the sharp decline in household deposits during 2016 contrasts with the continued, albeit slower, increase in non-oil GDP, suggesting that banking deposits may be more sensitive to macroeconomic shocks and financial sector adjustments than real economic activity.

Table 1 defines the variables employed in the analysis, distinguishing between the inflation-adjusted level variables used to represent household bank deposits and non-oil economic output, and their corresponding annual logarithmic growth rates, which serve as the dependent and independent variables in the linear and nonlinear Granger causality models.

The level variables display pronounced upward trends. Estimating Granger models directly in trending levels could generate misleading predictive relationships. Therefore, both series are transformed into annual logarithmic growth rates:

$$GDEP_t = 100\left[\ln\left(DEP_t\right) - \ln\left(DEP_{t-1}\right)\right], \quad (1)$$

$$GNOGDP_t = 100\left[\begin{matrix}\ln\left(NOGDP_t\right)\\ -\ln\left(NOGDP_{t-1}\right)\end{matrix}\right]. \quad (2)$$

The transformation reduces the effective sample from 25 level observations to 24 annual growth observations covering 2001–2024. Real deposit growth is substantially more volatile than non-oil GDP growth. Table 2 shows that, during the period under review, real household deposit growth was considerably more volatile than real non-oil GDP growth, exhibiting a higher average annual growth rate (15.72% versus 7.15%) and a much wider range of fluctuations. While both variables experienced periods of contraction and expansion, the substantially larger minimum and maximum values for deposit growth suggest that household deposits were more sensitive to macroeconomic and financial shocks than non-oil economic activity.

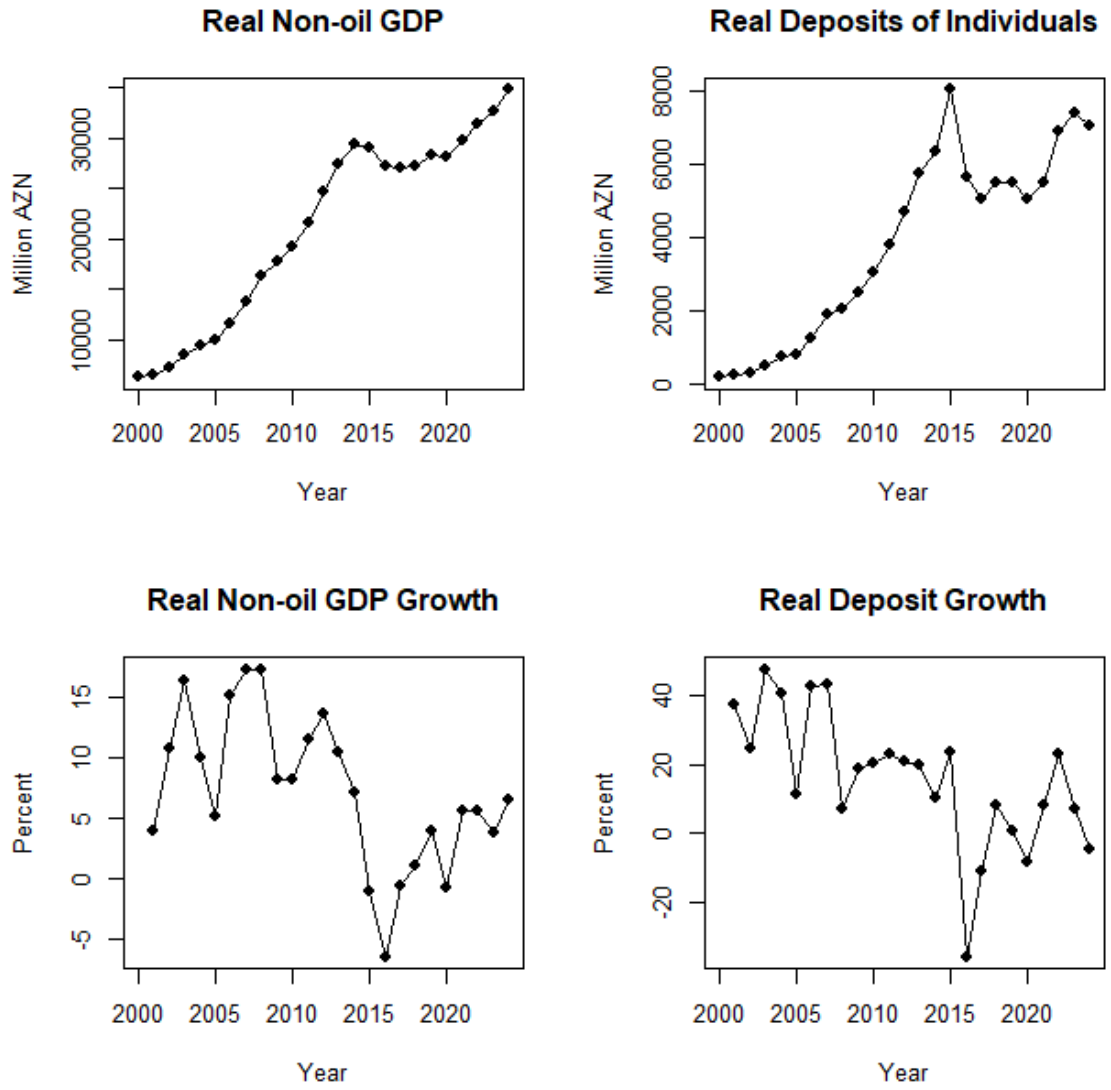
Table 2. Descriptive statistics of the growth variables

Statistic	Real deposit growth (%)	Real non-oil GDP growth (%)
Mean	15.718	7.151
Minimum	–35.743	–6.555
First quartile	7.125	3.921
Median	19.341	6.724
Third quartile	23.857	10.901
Maximum	47.461	17.314

Figure 2 shows that both real non-oil GDP and real household deposits exhibited a strong long-term upward trend over 2000–2024, although deposits experienced a pronounced decline in 2016 before partially recovering, whereas non-oil GDP resumed a more stable growth path. The growth-rate panels further reveal that household deposit growth was substantially more volatile than non-oil GDP growth, indicating that deposits were more sensitive to macroeconomic and financial shocks despite the sustained expansion of the non-oil economy.

Table 1. Variable definitions

Variable	Symbol	Measurement	Role
Real deposits of individuals in banks	DEP_t	Constant 2010 prices, million AZN	Dependent variable
Real non-oil gross domestic product	$NOGDP_t$	Constant 2010 prices, million AZN	Independent variable
Real deposit growth	$GDEP_t$	$100\Delta\ln(DEP_t)$	Dependent variable in causality models
Real non-oil GDP growth	$GNOGDP_t$	$100\Delta\ln(NOGDP_t)$	Independent variable in causality models



Note: The upper panels report constant-price levels in million AZN. The lower panels report annual logarithmic growth rates

Figure 2. Evolution of real non-oil GDP and real household deposits in Azerbaijan, 2000–2024

Household deposits in Azerbaijan include both manat- and foreign-currency-denominated balances. This distinction is particularly relevant during the 2015–2016 exchange-rate adjustment, because the manat value of foreign-currency deposits could increase mechanically following depreciation even without a corresponding increase in household saving. Consequently, part of the observed deposit dynamics around the crisis period may reflect valuation effects rather than changes in underlying saving behavior.

2.2. Methodology

This study investigates the predictive relationship between real non-oil GDP growth and real household deposit growth in Azerbaijan by comparing conventional linear Granger causality with a nonlinear Kernel Granger causality framework. The linear Granger causality test is first employed as a benchmark to determine whether past values of non-oil GDP growth improve the prediction of current deposit growth beyond the information contained in its own lagged values (Granger, 1969). The restricted and unrestricted linear models are specified as:

$$GDEP_t = \alpha_0 + \alpha_1 GDEP_{t-1} + \varepsilon_t, \quad (3)$$

$$GDEP_t = \beta_0 + \beta_1 GDEP_{t-1} + \beta_2 GNOGDP_{t-1} + \nu_t, \quad (4)$$

where $GDEP_t$ denotes the annual growth rate of real household deposits, and $GNOGDP_t$ represents

http://dx.doi.org/10.21511/bbs.21(4).2026.09

the annual growth rate of real non-oil GDP. A formal test of crisis-sensitivity is beyond the scope of the current specification; instead, robustness to the 2015–2016 episode is assessed via the leave-one-year-out procedure reported in the Appendix, which serves as a non-parametric analogue to a pulse-dummy control. To test directly whether the linear predictive relationship is structurally stable or an artifact of the 2015–2016 macro-financial shock, the unrestricted specification is augmented with a pulse dummy:

$$GDEP_t = \beta_0 + \beta_1 GDEP_{t-1} + \beta_2 GNOGDP_{t-1} + \beta_3 D2016 + \nu_t, \quad (5)$$

where $D_{2016} = 1$ for observations in 2016 and 0 otherwise. This provides a direct within-model test of crisis sensitivity and complements, rather than replaces, the leave-one-year-out robustness analysis reported in the Appendix.

The null hypothesis is:

$$H_0 : \beta_2 = 0, \quad (6)$$

indicating that lagged non-oil GDP growth does not Granger-cause deposit growth. The reverse direction of causality is also examined. Since economic relationships may exhibit nonlinear dynamics that cannot be adequately captured by linear models, the analysis further employs the Kernel Granger causality approach based on Kernel Ridge Regression. The restricted and unrestricted nonlinear specifications are given by:

$$GDEP_t = f_{R(GDEP_{t-1})} + \varepsilon_{R,t}, \quad (7)$$

$$GDEP_t = f_{U(GDEP_{t-1}, GNOGDP_{t-1})} + \varepsilon_{U,t}, \quad (8)$$

where $f_R(\cdot)$ and $f_U(\cdot)$ denote unknown nonlinear functions estimated through Kernel Ridge Regression using a Radial Basis Function (RBF) kernel. The kernel function is defined as:

$$K\left(x_i, x_j\right) = \exp\left(-\gamma x_i - x_j^{\,2}\right), \quad (9)$$

where $\gamma > 0$ controls the smoothness of the nonlinear mapping. The corresponding kernel ridge estimator is:

$$\hat{\alpha} = \left(K + \lambda I\right)^{(-1)y}, \quad (10)$$

where λ denotes the regularization parameter that controls model complexity and reduces overfitting (Saunders et al., 1998).

To avoid look-ahead bias, model performance is evaluated using expanding-window rolling-origin time-series cross-validation. At each forecasting origin, the model is estimated only from observations available up to that point, while the estimation window is recursively expanded by one observation. The kernel hyperparameters (γ and λ) are selected through grid-search optimization by minimizing the rolling forecast mean squared error (Bergmeir & Benítez, 2012). The nonlinear predictive contribution of non-oil GDP growth is quantified using the Kernel Granger Causality (KGC) statistic:

$$KGC = \ln\left(\frac{MSE_R}{MSE_U}\right), \quad (11)$$

where MSE_R and MSE_U denote the rolling forecast mean squared errors of the restricted and unrestricted models, respectively. Positive values indicate improved forecasting performance after incorporating lagged non-oil GDP growth.

Finally, statistical significance is evaluated using a circular-shift permutation test, which preserves the temporal dependence structure while generating the empirical null distribution of the Kernel Granger statistic. The permutation p-value is calculated as:

$$p = \frac{1 + \sum_{b=1}^{B} I\left(KGC_b \geq KGC_{obs}\right)}{B + 1}, \quad (12)$$

where p denotes the permutation-based *p-value*, B is the total number of permutations, $I(\cdot)$ is the indicator function that takes the value of 1 when the permuted Kernel Granger causality statistic KGC_b is greater than or equal to the observed statistic KGC_{obs} and 0 otherwise, KGC_b is the Kernel Granger causality statistic computed from the b permuted sample, and KGC_{obs} is the Kernel Granger causality statistic obtained from the original data.

The rolling-origin procedure used an initial estimation window of eight observations to generate 15 sequential one-step-ahead forecasts, with

standardization and model estimation based exclusively on the information available at each forecasting origin. Kernel hyperparameters (γ and λ) were selected through time-series cross-validation over predefined parameter grids, thereby avoiding look-ahead bias. Statistical inference relied on all 23 non-zero circular shifts of the predictor series, with hyperparameter tuning repeated for each permutation to incorporate model-selection uncertainty into the empirical null distribution.

3. RESULTS

3.1. Preliminary time-series properties and model specification

Prior to estimating the Granger causality models, the stationarity properties of the variables were examined because non-stationary time series may produce spurious regression results and invalidate statistical inference. To ensure the reliability of the empirical analysis, the Augmented Dickey–Fuller (ADF) (Dickey & Fuller, 1979), Phillips-Perron (PP) (Phillips & Perron, 1988), and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) (Kwiatkowski et al., 1992) unit root tests were employed, as these tests provide complementary evidence regarding the stochastic properties of the data.

Table 3 indicates that the logarithmic level variables are non-stationary, as the ADF and PP tests fail to reject the unit root hypothesis, while the KPSS test rejects stationarity, confirming that both real non-oil GDP and real household deposits exhibit strong trending behavior. After transforming the series into annual growth rates, the evidence becomes more favorable for stationarity, with the PP test rejecting the unit root for real deposit growth and the trend KPSS test failing to reject stationarity for both growth series, although the ADF results remain insignificant. Overall, despite some inconsistencies among the unit root tests due to the limited sample size, the growth-rate specification is preferred because it substantially reduces non-stationarity and provides a more appropriate basis for the subsequent Granger causality analysis.

A preliminary Engle–Granger regression was estimated in logarithmic levels:

$$\ln DEP_t = \alpha + \beta \ln NOGDP_t + u_t. \quad (13)$$

The estimated coefficient for log real non-oil GDP (Table 4) is 2.0862 and is statistically significant, while the model explains approximately 97.6% of the variation in log real household deposits. Nevertheless, this strong fit should be interpreted cautiously, as the non-stationarity of both level variables may inflate the explanatory power and produce a potentially spurious relationship. The residual-based ADF test yields a statistic of –3.5335 with a conventional p-value of 0.0592, indicating only weak evidence of residual stationarity at the 10% significance level. Since this p-value is based on standard ADF critical values rather than the specialized Engle–Granger distribution, the result is regarded as suggestive evidence of cointegration rather than a definitive confirmation of a stable long-run relationship.

Table 4. Preliminary log-level relationship

Parameter/statistic	Estimate
Intercept	–12.6853
Coefficient on log real non-oil GDP	2.0862
Standard error of slope	0.0683
t-statistic of slope	30.54
Regression (R^2)	0.9759
Residual ADF statistic	–3.5335
Conventional residual ADF p-value	0.0592

The lag length in Table 5 was selected from a maximum of two annual lags using the Akaike

Table 3. Unit root tests

Variable	ADF statistic	ADF p-value	PP statistic	PP p-value	KPSS level	KPSS level p-value	KPSS trend	KPSS trend p-value
Log real non-oil GDP	–1.3701	0.8123	–0.7928	0.9506	0.8519	< 0.01	0.2285	< 0.01
Log real deposits	–2.0316	0.5604	–1.4939	0.7652	0.8044	< 0.01	0.2355	< 0.01
Real non-oil GDP growth	–1.7462	0.6691	–2.9407	0.2140	0.4596	0.0515	0.0993	> 0.10
Real deposit growth	–1.8724	0.6210	–4.3115	0.0124	0.6786	0.0155	0.0949	> 0.10

Note: For ADF and PP, the null hypothesis is a unit root. For KPSS, the null hypothesis is stationarity. The different conclusions across tests should be interpreted in light of the very small sample.

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information criterion, Hannan–Quinn criterion, Schwarz criterion, and final prediction error. All four criteria selected one lag.

Table 5. Lag-selection results

Criterion	Lag 1	Lag 2	Selected lag
AIC	8.5882	8.7417	1
HQ	8.6583	8.8586	1
SC	8.8858	9.2377	1
FPE	5,386.5645	6,360.6809	1

The causality models therefore evaluate whether GNOGDPt–1 improves the prediction of GDEPt. For the restricted model, the lowest rolling-origin MSE is obtained at:

$$\gamma_R = 0.001, \quad \lambda_R = 0.005. \tag{14}$$

For the unrestricted model, the selected parameters are:

$$\gamma_U = 0.001, \quad \lambda_U = 0.010. \tag{15}$$

3.2. Kernel Granger causality results

Table 6 presents the optimal hyperparameters selected through rolling-origin cross-validation for the Kernel Ridge Regression models. Both the restricted and unrestricted models selected a very small kernel width (γ = 0.001), indicating that the underlying relationship between the variables is relatively smooth rather than highly nonlinear or locally complex. Although the unrestricted model employs a slightly larger regularization parameter (λ = 0.010) than the restricted model (λ = 0.005), it achieves a lower rolling cross-validation mean squared error (376.1621 versus 402.4179), suggesting that the inclusion of lagged non-oil GDP growth improves out-of-sample predictive performance while maintaining adequate control over model complexity.

The unrestricted model performs moderately better than the restricted model across all three reported loss functions. Table 7 demonstrates that the unrestricted Kernel Ridge Regression model consistently achieves lower forecasting errors than the restricted model, indicating that incorporating lagged real non-oil GDP growth improves the prediction of household deposit growth. Although the reductions in MSE (6.52%), RMSE (3.32%), and MAE (7.06%) suggest a modest enhancement in out-of-sample forecasting accuracy, these improvements alone do not constitute evidence of statistically significant nonlinear causality and should be interpreted alongside the subsequent Kernel Granger significance test.

Table 7. Rolling-origin forecast performance

Model	MSE	RMSE	MAE
Restricted	402.4179	20.0604	14.0930
Unrestricted	376.1621	19.3949	13.0976
Change after adding non-oil GDP growth	–6.52%	–3.32%	–7.06%

These reductions show that lagged non-oil GDP growth contains some incremental forecasting information in the observed sample. However, forecast improvement must not automatically be interpreted as statistically significant nonlinear causality. The resulting Kernel Granger statistic is:

$$KGC = \ln\left(\frac{402.4179}{376.1621}\right) = 0.0675. \tag{16}$$

Although the positive *KGC* statistic reflects the lower forecast error of the unrestricted model, the circular-shift permutation test yields a non-significant p-value of 0.4167, indicating that the observed improvement is not statistically significant. The null hypothesis of no nonlinear Granger causality therefore cannot be rejected at either the 5% or 10% significance level. Table 8 indicates that the observed forecasting improvement is insufficient to establish statistically significant nonlinear Granger causality. Therefore, the null hypothesis cannot be rejected.

The observed statistic is not unusually large relative to the placebo statistics generated by the circular shifts. In fact, several shifted alignments

Table 6. Selected kernel ridge parameters

Model	Predictors	Optimal γ	Optimal λ	Rolling CV MSE
Restricted	$GDEP_{t-1}$	0.001	0.005	402.4179
Unrestricted	$GDEP_{t-1}$, $GNOGDP_{t-1}$	0.001	0.010	376.1621

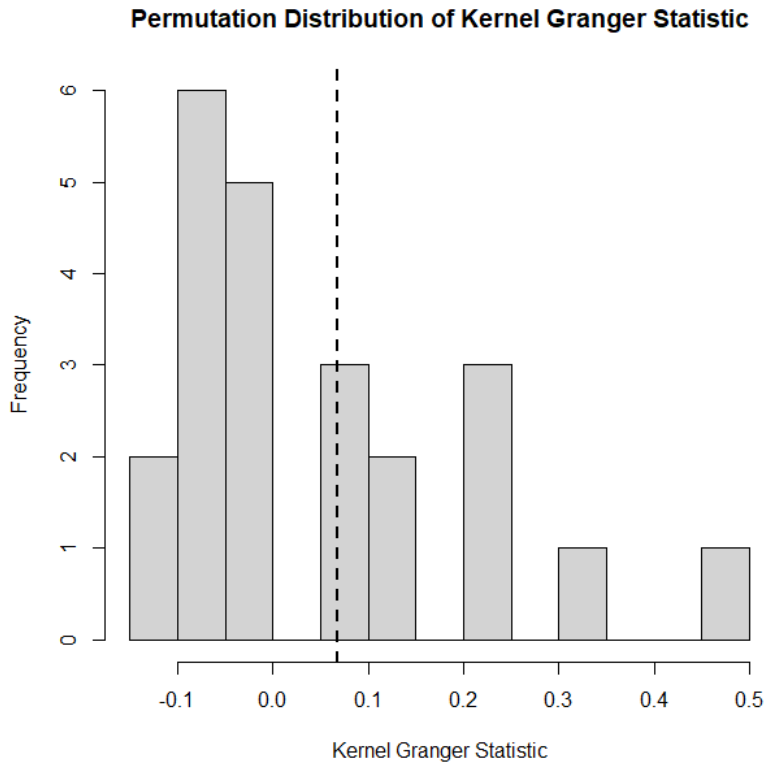
Table 8. Kernel Granger causality results

Causal direction	Lag	Restricted MSE	Unrestricted MSE	RMSE improvement	Kernel statistic	Permutation p-value	Decision
Non-oil GDP growth → Deposit growth	1	402.41	376.16	3.32%	0.067	0.416	Fail to reject H_0

produce substantially larger kernel statistics than the true temporal alignment. This indicates that the modest forecast gain is not sufficiently distinct from improvements that could arise through alternative temporal arrangements in such a short and volatile sample. Figure 3 shows that the observed Kernel Granger statistic lies well within the permutation distribution, indicating that it is not sufficiently extreme to provide evidence of statistically significant nonlinear Granger causality.

Given that the kernel hyperparameters were selected by minimizing MSE over the same rolling-origin forecasts used to evaluate model performance, the resulting MSE, RMSE, MAE, and KGC estimates should be interpreted as cross-validation-based model-selection measures rather than as fully independent out-of-sample forecasts. Consequently, the reported 6.52% improvement in MSE may be subject to some degree of optimistic selection bias.

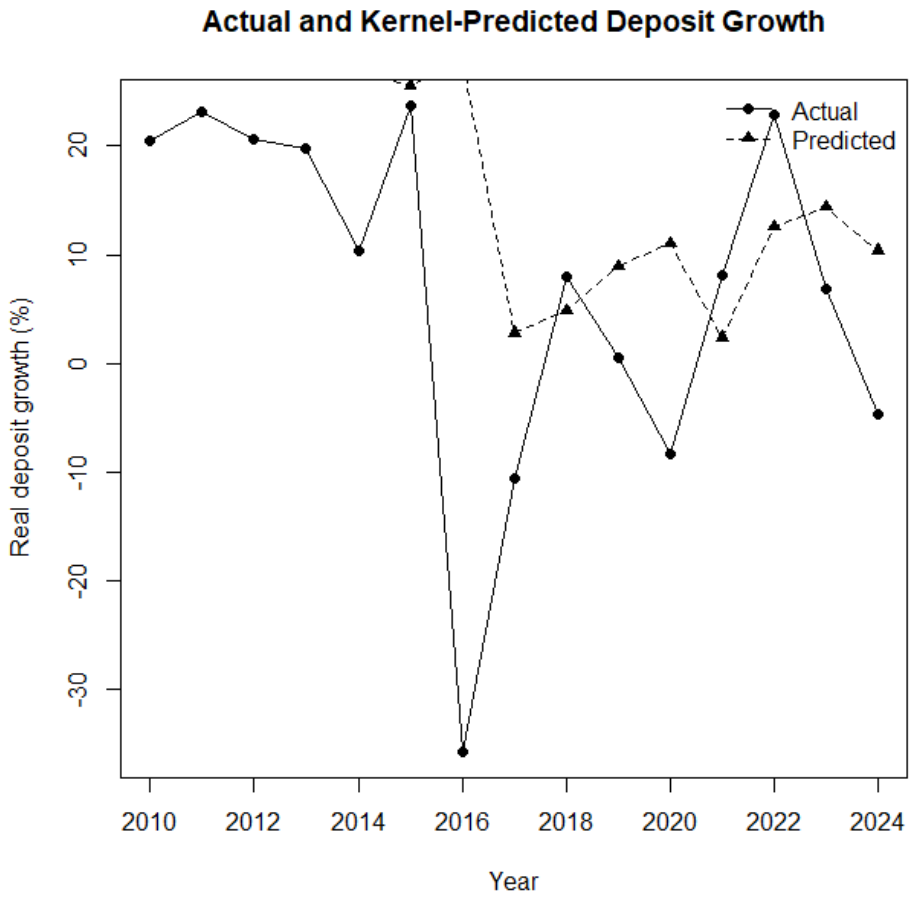
Figure 4 compares the actual and kernel-predicted values of real household deposit growth, showing that the unrestricted kernel model captures the general post-2016 recovery pattern but struggles to reproduce sharp fluctuations. The largest forecasting error occurs during the pronounced decline in 2016, suggesting that abrupt macro-financial shocks cannot be adequately explained by lagged deposit growth and non-oil GDP growth alone. Overall, the predicted series follows the broad direction of deposit growth but produces smoother fluctuations than the actual observations, indicating limited ability to capture extreme changes.



Note: The dashed vertical line indicates the observed statistic of 0.0675. The permutation p-value is 0.4167. Because a sizeable proportion of placebo statistics equals or exceeds the observed value, nonlinear Granger causality is not supported.

Figure 3. Circular-shift permutation distribution of the Kernel Granger statistic

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Note: Predictions are generated recursively from an expanding estimation window. Predictor and outcome standardization parameters are recalculated using only observations available before each forecast year.

Figure 4. Actual and rolling-origin kernel-predicted real deposit growth, 2010–2024

3.3. Linear Granger causality and model diagnostics

The conventional linear Granger test gives a different conclusion from the nonlinear kernel test. For the direction:

$$GNOGDP_{t-1} \rightarrow GDEP_t. \quad (17)$$

The test statistic is:

$$F = 5.3058, \quad p = 0.0321. \quad (18)$$

The null hypothesis is rejected at the 5% level. Thus, past real non-oil GDP growth provides statistically significant linear predictive information for current real household deposit growth. The reverse test evaluates whether lagged deposit growth predicts non-oil GDP growth. It produces:

$$F = 0.1656, \quad p = 0.6884. \quad (19)$$

The reverse null hypothesis cannot be rejected. The evidence therefore supports unidirectional linear Granger causality from non-oil GDP growth to deposit growth. Table 9 indicates statistically significant unidirectional linear Granger causality from real non-oil GDP growth to household deposit growth ($F = 5.3058$, $p = 0.0321$). However, the leave-one-year-out robustness analysis shows that this finding is sensitive to the 2016 observation: excluding 2016 increases the p-value to 0.3813, whereas the relationship remains significant when other individual years are omitted. Accordingly, the full-sample evidence should be interpreted as crisis-sensitive predictive causality rather than as a structurally stable relationship over the entire sample period. A formal pulse-dummy specification for 2015–2016 was not estimated in the current framework; the leave-one-year-out result is offered as suggestive rather than definitive evidence of this sensitivity, and it should be tested directly in future research.

Table 9. Linear Granger causality results

Causal direction	Lag	F-statistic	p-value	Decision at 5%
Non-oil GDP growth → deposit growth	1	5.3058	0.0321	Reject H_0
Deposit growth → non-oil GDP growth	1	0.1656	0.6884	Fail to reject H_0

Table 10 shows that once the 2015–2016 crisis pulse is included, the coefficient on lagged non-oil GDP growth falls from 1.818 to 0.689 and loses statistical significance (robust SE = 0.437, 95% CI [−0.169, 1.546], p = 0.115), while the crisis dummy is large, negative, and highly significant (β = −48.966, robust SE = 5.390, p < 0.001). This indicates that the 2016 deposit collapse – a decline of roughly 35.7 percentage points in a single year – rather than non-oil GDP growth, accounts for most of the variation previously attributed to it in Table 9. Together, these results confirm that the full-sample linear Granger result does not reflect a structurally stable relationship between non-oil GDP growth and household deposit growth, but is instead concentrated in the 2015–2016 macro-financial shock, corroborating the leave-one-year-out sensitivity reported in the Appendix.

To partially address the asymmetry in diagnostic reporting between the linear and kernel models, Breusch-Pagan and Shapiro-Wilk tests were also applied to the residuals of the linear Granger model, thereby providing a more comprehensive diagnostic assessment. Table 11 was not pursued given the limited sample size. Table 11 presents the diagnostic tests applied to the rolling forecast residuals of the unrestricted Kernel Ridge Regression model to assess residual autocorrelation, conditional heteroskedasticity, and distributional properties. The Ljung-Box and ARCH-LM tests fail to reject their respective null hypotheses, indicating that the residuals are free from significant serial correlation and conditional heteroskedasticity. These findings suggest that the model adequately captures the temporal dependence structure of the data and produces stable forecast errors.

In contrast, the Shapiro–Wilk test rejects the null hypothesis of normality, implying that the residuals deviate from a Gaussian distribution. This result is largely attributable to the exceptionally large forecast error observed during the 2016 financial shock, which exerts a disproportionate influence in a relatively small sample of rolling forecast residuals. Nevertheless, this departure from normality does not undermine the validity of the Kernel Granger inference because statistical significance is established through a non-parametric permutation procedure rather than distributional assumptions. Overall, the diagnostic results support the adequacy of the estimated kernel model while suggesting that the nonlinear predictive relationship should be interpreted with appropriate caution in light of the observed structural instability.

4. DISCUSSION

The combined linear and nonlinear evidence offers a clear picture of household deposit dynamics in Azerbaijan. Deposit growth is shaped far more

Table 10. Linear Granger regression with 2015–2016 crisis control

Parameter	Estimate	Robust SE	95% CI	z	p
Intercept	7.148	3.796	[−0.293, 14.588]	1.883	0.060
$GDEP_{(t-1)}$	0.290	0.133	[0.028, 0.551]	2.171	0.030
$GNOGDP_{(t-1)}$	0.689	0.437	[−0.169, 1.546]	1.574	0.115
D_{2016}	−48.966	5.390	[−59.531, −38.402]	−9.084	0.000

Note: n = 23 (2002–2024). Standard errors are heteroskedasticity-robust (HC1). D2016 is a pulse dummy equal to 1 in 2016 and 0 otherwise, controlling for the 2015–2016 macro-financial crisis and exchange-rate adjustment.

Table 11. Residual diagnostic tests

Diagnostic test	Statistic	Degrees of freedom	p-value	Conclusion
Ljung-Box	0.6853	3	0.8767	No residual autocorrelation
ARCH-LM	0.2759	2	0.8711	No ARCH effect
Shapiro-Wilk	0.7631	–	0.0013	Normality rejected

http://dx.doi.org/10.21511/bbs.21(4).2026.09

by macro-financial shocks than by the gradual expansion of the non-oil economy. The full-sample linear Granger test identifies unidirectional predictive causality from non-oil GDP growth to deposit growth ($F = 5.3058$, $p = 0.0321$), with no reverse effect ($F = 0.1656$, $p = 0.6884$). The crisis-adjusted specification (Table 10) shows where this signal originates. Once the 2016 pulse is introduced, the coefficient on lagged non-oil GDP growth declines from 1.818 to 0.689 and becomes statistically insignificant ($p = 0.115$). The crisis dummy, by contrast, is large and highly significant ($\beta = -48.966$, $p < 0.001$). The leave-one-year-out analysis confirms this pattern (Figure A1). The full-sample linear association is therefore concentrated in the 2015–2016 macro-financial episode rather than distributed across the sample period.

The nonlinear analysis complements this result. The unrestricted Kernel model reduces the cross-validated MSE from 402.42 to 376.16, but the Kernel Granger statistic (KGC = 0.0675) is not significant under the circular-shift permutation test ($p = 0.4167$). The absence of significant evidence in both frameworks indicates that, outside the crisis episode, lagged non-oil growth adds little systematic information about household deposit growth. This holds for both linear and nonlinear functional forms. Figure 5 summarizes the comparison across the three tests.

The central role of the 2015–2016 episode is itself an informative result. During this period, Azerbaijan experienced the oil price collapse, the transition to a floating exchange rate with substantial manat depreciation, a rise in inflation, and the restructuring of the banking sector. These developments affected household deposits through channels largely independent of real non-oil activity. The first channel is valuation. Because a considerable share of household deposits is held in foreign currency, exchange-rate movements alter the manat value of balances without any change in saving behavior. The second channel is inflation. Higher post-devaluation inflation erodes the real value of manat-denominated savings. The third channel is confidence. Uncertainty about the banking system and the currency encourages withdrawals and portfolio shifts. The 2016 contraction in real deposits therefore reflects a shock to the financial system rather than an income-driven decline in household saving capacity. This explains why controlling for the episode substantially weakens the estimated link with non-oil growth.

These findings extend the existing evidence for Azerbaijan in an important direction. Mukhtarov et al. (2019) and Hasanov and Huseynov (2013) showed that bank credit supports non-oil output, which highlights the finance-to-growth channel of the banking sector. The present study examines the opposite channel, from non-oil growth to household deposits. It shows that this channel does not operate as a stable predictive mechanism over the sample period. The two lines of evidence therefore describe different transmission directions and should not be read as a single reinforcing loop. Together, they suggest an asymmetry: banks contribute to diversification through lending, while the deposit base that funds this lending remains exposed to external and monetary shocks. This interpretation agrees with Hasanov et al. (2025), who identified oil prices and inflation as significant determinants of household deposits in Azerbaijan. It is also consistent with Saif-Alyousfi et al. (2018), who documented the sensitivity of bank deposits to oil and gas price shocks in Qatar. It further agrees with Seyfullayev (2023), who found no long-run causality between financial development and non-resource growth. Taken together, the evidence indicates that in resource-dependent economies the link between real activity and household deposits is mediated by commodity-price, exchange-rate and inflation conditions. This adds a country-specific dimension to the broader finance–growth literature (Levine, 2005).

The study also makes a methodological contribution. It combines a conventional linear Granger test, a nonlinear Kernel Granger framework with permutation-based inference, and explicit crisis controls. This design distinguishes a persistent predictive relationship from one driven by a single macro-financial episode. A full-sample linear test alone would have suggested a stable growth-to-deposits link. The multi-method design shows that this conclusion depends on the treatment of the crisis. This approach is especially relevant for small annual samples from resource-dependent economies, where infrequent but severe shocks can dominate estimation results. From a poli-

cy perspective, the results suggest that non-oil growth alone is not sufficient to secure a stable household deposit base. Safeguarding deposit mobilization depends equally on exchange-rate and price stability, on reducing deposit dollarization, and on maintaining public confidence in the banking system. This is consistent with evidence that a broad and stable deposit base strengthens banking-sector resilience during periods of financial stress (Han & Melecky, 2013).

CONCLUSION

This study examined whether real non-oil economic growth contains predictive information for household bank deposit growth in Azerbaijan using complementary linear and nonlinear Granger frameworks. The full-sample linear specification indicates significant predictive causality from non-oil GDP growth to deposit growth; however, robustness analysis reveals that this result is sensitive to the 2016 crisis observation and therefore cannot be regarded as structurally stable evidence across the entire sample. The Kernel Granger analysis does not identify statistically significant nonlinear predictive improvement, although the small effective sample limits the power of the nonlinear test and prevents ruling out nonlinear dependence. Once the 2015–2016 crisis year is explicitly controlled for, the non-oil GDP growth effect disappears, showing that the earlier result was driven by that single shock rather than a stable underlying relationship.

The findings have important policy implications for both economic and financial authorities. Sustaining non-oil economic growth through diversification, employment creation, and private-sector development may strengthen household saving capacity and support a more stable deposit base. At the same time, maintaining confidence in the banking system through sound financial regulation, macroeconomic stability, and effective risk management remains essential, particularly during periods of economic uncertainty. Future research could extend the analysis by employing higher-frequency data and incorporating additional financial and macroeconomic variables, such as interest rates, inflation, exchange rates, remittances, and banking-sector indicators. Applying alternative nonlinear and regime-switching models or conducting cross-country comparisons among resource-dependent economies would also provide a deeper understanding of the macro-financial determinants of household bank deposits.

AUTHOR CONTRIBUTIONS

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Software: Ramil I. Hasanov.
Supervision: Juan A. Parrilla González, Aynur Jabbarova, Laman Ahmadova.
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Writing – original draft: Ramil I. Hasanov.
Writing – reviewing & editing: Zeynab Giyasova, Juan A. Parrilla González, Aynur Jabbarova, Naila Akhundova, Laman Ahmadova.

http://dx.doi.org/10.21511/bbs.21(4).2026.09

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http://dx.doi.org/10.21511/bbs.21(4).2026.09

APPENDIX A

Figure A1 presents the leave-one-year-out robustness analysis for the linear Granger causality test. The results show that the full-sample finding remains statistically significant after excluding most individual years, although omitting 2016 causes the p-value to rise above the 5% significance threshold, indicating that the detected linear predictive relationship is sensitive to the 2015–2016 financial shock.

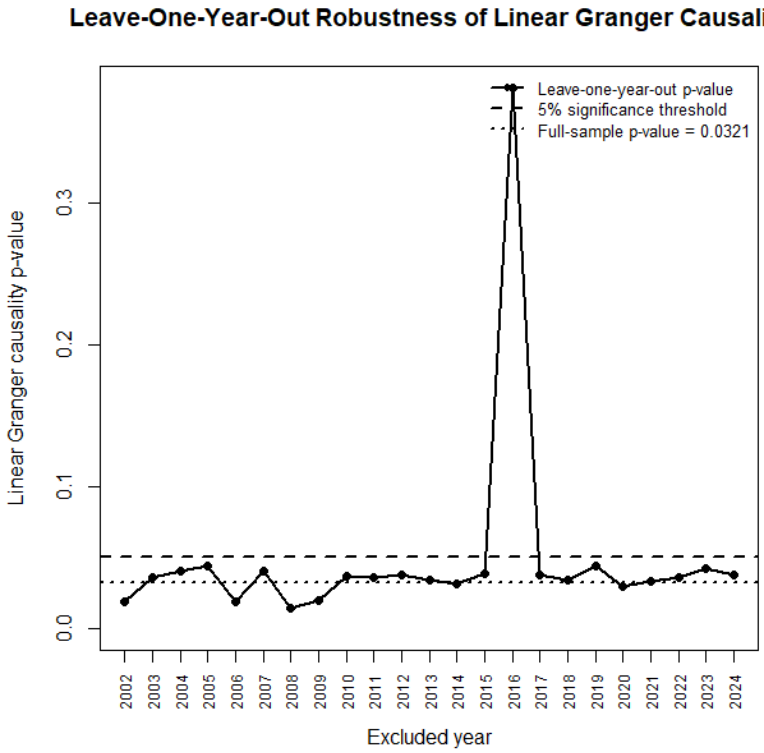


Figure A1. Leave-one-year-out robustness of linear Granger causality

Figure A2 highlights the contrast between the linear and nonlinear causality results, showing that only the linear Granger test identifies a statistically significant predictive effect from non-oil GDP growth to household deposit growth. In contrast, neither the nonlinear Kernel Granger test nor the reverse-direction linear Granger test provides evidence of statistically significant causality.

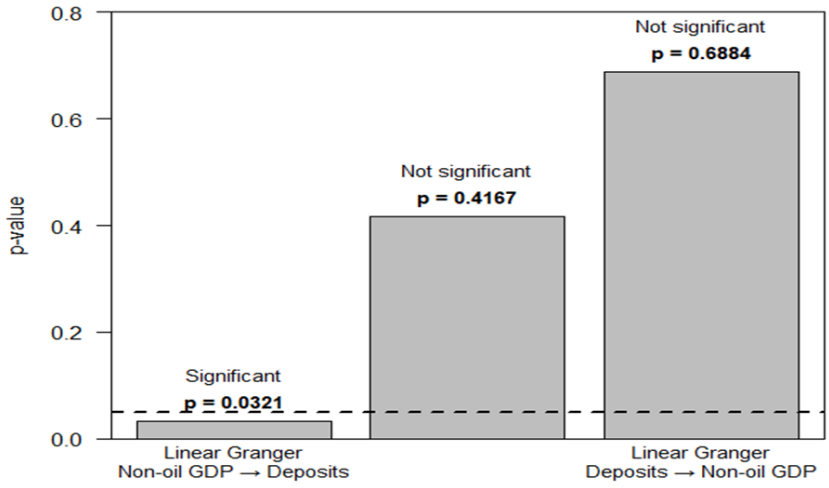


Figure A2. Comparison of linear and nonlinear Granger causality results