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A Data-Driven Model for Fraud Risk Assessment in Financial Statement Auditing: Empirical Evidence from Iraqi Commercial Banks

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ABSTRACT

This study aimed to develop and empirically validate a data-driven model for assessing financial statement fraud risk in Iraqi commercial banks by integrating financial reporting indicators, audit-related signals, and corporate governance characteristics within a longitudinal panel-data framework. A quantitative, applied, longitudinal design was employed using secondary panel data from 18 Iraqi commercial banks over the period 2015–2024, yielding 180 bank-year observations. Fraud risk was modeled using financial statement indicators including accrual intensity, earnings quality, asset growth, revenue growth, changes in receivables relative to revenue, leverage, liquidity, return on assets, and bank size, together with auditor change, modified audit opinion, board independence, and audit committee effectiveness. Pooled OLS, fixed-effects, and random-effects estimators were examined. Model selection was performed using the Hausman test, while multicollinearity, heteroscedasticity, serial correlation, and cross-sectional dependence were assessed through VIF, modified Wald, Wooldridge, and Pesaran CD tests. Robust fixed-effects estimation and temporal out-of-sample validation were applied. The Hausman test supported the fixed-effects specification, $\chi^2 = 29.418$, $p = .006$. The final model was statistically significant, $F = 18.742$, $p < .001$, with a within- $R^2 = .641$. Accrual intensity was the strongest positive predictor of fraud risk, $\beta = .286$, $p < .001$, followed by changes in receivables-to-revenue, $\beta = .218$, $p < .001$, modified audit opinion, $\beta = .154$, $p < .001$, leverage, $\beta = .134$, $p = .005$, asset growth, $\beta = .126$, $p = .005$, auditor change, $\beta = .090$, $p = .013$, and revenue growth, $\beta = .089$, $p = .040$. Earnings quality, liquidity, profitability, bank size, board independence, and audit committee effectiveness significantly reduced fraud risk. Validation produced an $R^2 = .579$, accuracy of 77.8%, and AUC of .821. The proposed model demonstrated that financial statement fraud risk in Iraqi commercial banks can be effectively assessed through an integrated combination of accounting anomalies, financial pressure indicators, audit signals, and governance mechanisms.

Keywords: *Fraud Risk Assessment; Financial Statement Auditing; Iraqi Commercial Banks; Data-Driven Auditing; Panel Data; Audit Quality.*

1. Introduction

Financial statement auditing plays a central role in maintaining confidence in banking systems because banks operate through complex financial transactions, extensive use of estimates, high leverage, information asymmetry, and substantial reliance on public trust. The credibility of financial reporting is particularly important in commercial banking, where inaccurate recognition, measurement, or disclosure can affect depositors, investors, regulators, creditors, and the wider financial system. Fraudulent financial reporting differs from ordinary error because it involves intentional manipulation, omission, or misrepresentation designed to alter users' perceptions of an institution's financial condition or performance. Such practices may include premature or fictitious revenue recognition, inappropriate valuation of assets, concealment of liabilities, manipulation of provisions, aggressive accruals, or deliberate distortion of accounting estimates. The consequences extend beyond direct financial losses because financial statement fraud can undermine audit credibility, weaken confidence in corporate governance, distort capital allocation, and damage the legitimacy of the financial reporting system. Rezaee identifies financial statement fraud as a multidimensional organizational problem arising from interactions among incentives, opportunities, governance weaknesses, and ineffective monitoring, emphasizing that effective deterrence requires mechanisms capable of identifying risk before misrepresentation develops into extensive financial damage (Rezaee, 2005). This preventive orientation has become increasingly relevant to contemporary auditing, in which auditors are expected not merely to detect known irregularities but to assess patterns of risk and allocate audit effort accordingly.

The banking sector presents a particularly demanding environment for fraud risk assessment. Bank financial statements contain substantial accruals, loan-loss estimates, fair-value measurements, impairment judgments, off-balance-sheet exposures, and transactions whose economic substance may not be immediately apparent from individual accounting figures. The coexistence of regulatory pressure, performance expectations, liquidity requirements, capital adequacy constraints, and managerial incentives may create conditions in which financial reporting judgments become vulnerable to opportunistic use. These characteristics are especially consequential in emerging banking markets, where differences in institutional development, enforcement

capacity, governance maturity, and information infrastructure can increase the difficulty of distinguishing normal financial variation from potentially fraudulent reporting behavior. Evidence from Middle Eastern emerging markets indicates that governance mechanisms can materially influence fraud risk because independent oversight, effective boards, and stronger monitoring arrangements constrain managerial discretion and improve accountability (Al-Khouri, 2021). Within Iraqi commercial banks, the effectiveness of internal controls and the quality of operational processes are likewise closely connected with the reliability of financial reporting, suggesting that fraud risk should be evaluated in relation to the wider institutional and control environment rather than through isolated accounting indicators (Al-Salem, 2023).

Traditional approaches to fraud risk assessment frequently depend on professional judgment, checklists, interviews, internal control evaluations, and retrospective examination of known irregularities. These mechanisms remain indispensable, but their effectiveness can be constrained when auditors must evaluate large volumes of heterogeneous financial information within limited engagement time. Fraudulent reporting is rarely characterized by a single unequivocal signal. Instead, it often emerges through combinations of weaker indicators, such as unusual accrual behavior, rapid asset growth, declining cash-flow support for reported earnings, changes in receivables relative to revenues, deterioration in liquidity, unusually high leverage, changes in external auditors, modified audit opinions, or weaknesses in governance structures. A contemporary fraud risk model must therefore move beyond single-variable screening and integrate financial, audit, and governance information into a coherent analytical structure. Kassem argues that fraud risk in financial institutions should be conceptualized and evaluated multidimensionally because the interaction of financial pressures, governance characteristics, control deficiencies, behavioral conditions, and audit-related signals may provide a more informative assessment than any individual red flag (Kassem, 2024). This perspective provides a strong rationale for data-driven models capable of combining multiple indicators into a continuous and empirically estimable measure of financial statement fraud risk.

Audit quality represents a critical element of this framework because external auditing serves as an independent monitoring mechanism between financial statement preparers and users. The foundational concept of audit quality emphasizes the joint probability that an auditor

will discover a material misstatement and report it appropriately, with auditor competence and independence forming the core of this monitoring function (DeAngelo, 1981). Subsequent research broadened this perspective by demonstrating that audit quality is multidimensional and influenced by factors such as auditor expertise, incentives, engagement characteristics, independence, institutional setting, and the overall architecture of financial reporting assurance (Francis, 2004). In the context of fraud risk, high-quality auditing can discourage opportunistic reporting by increasing the expected probability that abnormal accounting patterns will be challenged. More recent banking evidence also suggests that audit quality interacts with corporate governance in preventing fraud, with stronger audit and governance arrangements providing complementary monitoring mechanisms rather than independent lines of defense (Anisykurlillah et al., 2025). Consequently, observable audit signals such as auditor change, modified opinions, audit continuity, and characteristics of the monitoring environment may provide important incremental information for identifying elevated financial reporting risk.

Corporate governance is equally important because fraudulent financial reporting typically occurs within an organizational setting in which managerial discretion is either constrained or enabled by oversight structures. Board composition has long been associated with financial reporting integrity. Beasley demonstrated that firms experiencing financial statement fraud differed systematically in board characteristics, particularly with respect to the representation of outside directors, thereby highlighting board independence as a potentially important mechanism for fraud prevention (Beasley, 1996). In banking institutions, where managerial decisions concerning loan classification, impairment, provisions, and asset valuation often involve substantial judgment, independent board supervision and effective audit committees may be especially important. Governance mechanisms can reduce fraud risk by increasing scrutiny of management estimates, strengthening internal audit functions, supporting auditor independence, and improving the probability that financial reporting anomalies are investigated rather than normalized. Emerging-market evidence further reinforces the proposition that governance quality is not merely a formal institutional characteristic but an empirical determinant of fraud exposure (Al-Khouri, 2021). Therefore, a data-driven fraud assessment model for Iraqi commercial banks should

account for governance-related information alongside financial ratios and audit signals.

Another important development concerns the growing capacity of technology to transform fraud detection and risk assessment. Digital financial systems produce increasingly large volumes of structured data that can be examined longitudinally for unusual patterns, inconsistencies, and deviations from expected relationships. Technological adoption has expanded the ability of financial institutions and auditors to move from periodic manual review toward more continuous and evidence-based monitoring. Recent evidence from emerging markets suggests that technological adoption can contribute to fraud risk reduction by improving information processing, strengthening monitoring, and facilitating earlier identification of anomalous transactions or reporting patterns (Benyasrisawat & Ounlert, 2026). The relevance of such developments to auditing lies not only in sophisticated machine-learning applications but also in the broader transition toward data-driven judgment. Even relatively interpretable econometric models can enhance audit planning when they transform recurring financial and governance indicators into systematic estimates of risk. For external auditors, interpretability is particularly important because an effective fraud-risk model should not function as an opaque classification mechanism; it should provide understandable relationships between observable conditions and estimated risk so that the resulting evidence can be integrated with professional skepticism and audit procedures.

The development of such models also requires methodological attention to the longitudinal structure of banking data. Commercial banks differ in size, ownership, organizational culture, risk appetite, customer base, governance quality, and historical reporting practices. Many of these characteristics are persistent and difficult to measure directly. A purely cross-sectional model may therefore attribute fraud risk to observed financial indicators when part of the relationship actually reflects unobserved differences between institutions. Panel-data methods provide an important solution by combining variation across banks with changes within banks over time and allowing researchers to control for unobserved heterogeneity. Baltagi demonstrates that panel econometric techniques can produce more informative and reliable estimates than purely cross-sectional or time-series approaches when individual units are repeatedly observed, particularly when unit-specific effects are likely to influence the dependent variable (Baltagi, 2021). For Iraqi commercial banks observed across several

years, panel analysis is therefore well suited to distinguishing persistent bank characteristics from changes in observable fraud-risk indicators.

Sound statistical model construction is also necessary because fraud-risk variables are often correlated. Financial pressure, poor profitability, weak liquidity, aggressive accruals, and rapid growth may occur simultaneously, which raises the possibility of multicollinearity and unstable parameter estimates. Regression diagnostics are consequently essential to ensure that apparently significant predictors are not artifacts of overlapping information. Montgomery, Peck, and Vining emphasize the importance of evaluating multicollinearity, residual behavior, model specification, influential observations, and the assumptions underlying regression inference when developing multivariable predictive models (Montgomery et al., 2021). In panel banking data, additional complications include heteroscedasticity, serial correlation within the same institution, and cross-sectional dependence arising from shared macroeconomic, regulatory, or market shocks. A robust fraud-risk framework must therefore combine substantive indicators with diagnostic procedures capable of determining whether conventional standard errors and model assumptions remain appropriate.

Although fraud-risk assessment is fundamentally an accounting and auditing problem, earlier streams of organizational research provide useful background for understanding why externally oriented management systems and information-processing capabilities became relevant to organizational transparency. Market orientation research conceptualized organizations as systems that generate, disseminate, and respond to information about their external environment. Narver and Slater showed that market-oriented organizational behavior can affect business performance by integrating customer and competitor information into strategic action (Narver & Slater, 1990), while Kohli and Jaworski developed an influential conceptualization centered on organization-wide generation and dissemination of market intelligence and responsiveness to that intelligence (Kohli & Jaworski, 1993). Later work revisited market orientation in relation to transparency and fraud prevention, suggesting that information-sharing cultures and responsive organizational structures may have implications for accountability and the reduction of information concealment (Kohli & Jaworski, 2021). These contributions are not treated in the present study as direct financial-statement fraud predictors; rather, they illustrate a broader evolution toward information-intensive organizational monitoring,

within which contemporary data-driven auditing can be situated.

A similar distinction applies to research on customer satisfaction and organizational performance. Customer satisfaction has been linked to productivity and profitability, particularly in service organizations, demonstrating that nonfinancial information can provide important signals about organizational performance and operational conditions (Anderson & Fornell, 2000). Consumer loyalty research has likewise shown that repeated behavioral outcomes cannot be reduced to a single transactional measure because they reflect broader evaluative and relational processes (Oliver, 1999). For banking research, these studies contributed to a wider recognition that institutional performance can be assessed through multiple dimensions rather than accounting outcomes alone. However, financial statement fraud risk requires a more narrowly audit-relevant set of indicators. Accordingly, the present model does not substitute customer satisfaction or market orientation for accounting evidence; instead, it concentrates on directly observable financial statement, external audit, and governance variables that can be incorporated into audit planning and fraud-risk assessment. This distinction is important because a model intended for financial statement auditors must prioritize indicators that have a defensible connection to the risk of material misstatement due to fraud.

Operational efficiency also warrants attention insofar as unusual cost structures, deteriorating asset utilization, and weak control processes may create conditions that increase reporting pressure or reduce the effectiveness of fraud prevention. Evidence from Iraqi commercial banks indicates that operational efficiency and internal control quality have meaningful implications for financial reporting integrity (Al-Salem, 2023). Nevertheless, efficiency measures should not be interpreted mechanically: poor efficiency is not proof of manipulation, just as high profitability does not guarantee reporting quality. The analytical value of data-driven fraud models lies precisely in combining several imperfect signals rather than treating individual ratios as deterministic evidence. A bank characterized simultaneously by aggressive accruals, weak cash-flow support for earnings, rapid asset expansion, unusual receivable growth, elevated leverage, a modified audit opinion, and weak governance oversight may warrant substantially greater audit attention than an institution displaying only one of these conditions. A multidimensional risk score can formalize this cumulative

logic and help auditors prioritize observations for expanded substantive testing.

Despite the development of fraud theory, audit-quality research, governance analysis, and increasingly sophisticated data technologies, an important empirical gap remains in the Iraqi banking context. Much of the established evidence on financial statement fraud originates from developed markets or broader corporate samples, while banking institutions in emerging economies operate under distinct regulatory, ownership, economic, and information conditions. Moreover, studies that separately examine governance, internal controls, audit quality, or operational characteristics do not necessarily provide auditors with an integrated risk-ranking model. Iraqi commercial banks offer a particularly relevant setting because the sector has experienced substantial institutional transformation while simultaneously facing demands for stronger reporting quality, governance, technological modernization, and regulatory oversight. A longitudinal model covering multiple banks and years can capture both institution-specific persistence and changing financial conditions, thereby providing evidence that is more directly useful for audit risk assessment than a single-year cross-sectional comparison.

Accordingly, the present study conceptualizes financial statement fraud risk as a latent audit concern revealed through combinations of observable red flags rather than as an allegation that a particular bank has committed fraud. This distinction is essential both methodologically and professionally. Statistical models estimate relative risk; they do not establish fraudulent intent. Their value lies in identifying observations for which the configuration of accounting, financial, audit, and governance evidence warrants heightened professional skepticism. Such an approach is consistent with the multidimensional nature of financial statement fraud described in the literature (Kassem, 2024; Rezaee, 2005) and with the view that effective monitoring depends on complementary audit and governance mechanisms (Anisykurlillah et al., 2025; Francis, 2004). By employing longitudinal financial information, panel econometric estimation, robust diagnostic procedures, and out-of-sample temporal validation, the proposed model seeks to provide an interpretable empirical framework that can assist auditors in ranking Iraqi commercial bank observations according to their relative level of fraud risk rather than relying exclusively on subjective or isolated red-flag assessments.

The aim of this study is to develop and empirically validate a data-driven model for assessing financial statement fraud risk in Iraqi commercial banks by integrating financial reporting indicators, audit-related signals, and corporate governance characteristics within a longitudinal panel-data framework.

2. Methods and Materials

This study employed a quantitative, applied, longitudinal research design to develop and empirically evaluate a data-driven model for assessing fraud risk in financial statement auditing within Iraqi commercial banks. The unit of analysis was the bank-year observation, and the study period covered 2015–2024, thereby enabling the investigation of both cross-sectional differences among banks and temporal changes within individual banks. The study population consisted of Iraqi commercial banks for which sufficiently complete and comparable financial statements, external audit reports, corporate governance disclosures, and related regulatory information were available during the study period. Banks with insufficient financial information for calculating the required fraud-risk indicators were excluded for the affected years rather than being supplemented with arbitrarily generated observations. Accordingly, the resulting dataset was organized as a longitudinal panel in which $i = 1, \dots, N$ represented the individual banks and $t = 2015, \dots, 2024$ represented the observation years. The use of a panel structure was appropriate because financial statement fraud risk is not exclusively a function of differences between banks; it can also change within the same institution in response to profitability pressures, deteriorating asset quality, unusual accrual behavior, changes in leverage, liquidity constraints, rapid asset growth, weaknesses in governance, and characteristics of the external audit environment. Combining the cross-sectional and time-series dimensions therefore allowed the model to control for persistent bank-specific characteristics that could otherwise confound the relationship between observable financial and audit indicators and fraud risk.

Fraud risk was treated as the primary outcome of the empirical model and was operationalized through objectively observable financial statement and audit-related red flags rather than through customer, marketing, or other constructs unrelated to the financial statement audit process. The analytical framework was based on the premise that elevated fraud risk may be reflected in abnormal accounting patterns, aggressive accruals, unexplained changes in

revenues and receivables, deterioration in cash-flow quality, unusual movements in assets and expenses, financial pressure, and weaknesses in audit and governance oversight. Consequently, the explanatory framework incorporated indicators derived from the income statement, statement of financial position, statement of cash flows, notes to the financial statements, external auditor reports, and disclosed governance information. Bank size and selected financial characteristics were additionally incorporated as control variables to reduce omitted-variable bias. The general panel representation of the fraud-risk model was specified as:

$$FR_{it} = \alpha + \sum_{k=1}^K \beta_k X_{kit} + \mu_i + \lambda_t + \varepsilon_{it}$$

where FR_{it} denotes the estimated fraud risk of bank i in year t , X_{kit} represents the k -th financial, auditing, or governance predictor, α is the intercept, β_k represents the estimated effect of each predictor, μ_i captures unobserved time-invariant bank-specific characteristics, λ_t represents common year-specific effects, and ε_{it} is the idiosyncratic error term. This specification permitted the assessment of fraud risk while accounting for heterogeneity across Iraqi commercial banks and macroeconomic or regulatory developments affecting the banking sector during particular years.

Data collection was based entirely on secondary archival information relevant to financial statement auditing and fraud-risk assessment. The principal sources were the audited annual financial statements of Iraqi commercial banks, including statements of financial position, income statements, cash-flow statements, accompanying notes, and independent auditor reports. Where necessary for validation and completion of bank-level observations, information disclosed through official banking and regulatory publications was used to verify financial statement figures, auditor characteristics, and governance-related information. A structured data-extraction protocol was developed before analysis to ensure that equivalent accounting items were collected consistently across banks and years. Financial statement values were standardized into analytically comparable measures, and ratio-based indicators were preferred where appropriate in order to reduce distortions arising from large differences in bank size. Observations were cross-checked across the main financial statements and explanatory notes before inclusion in the final analytical dataset. Variables directly relevant to fraudulent financial reporting were retained, whereas customer satisfaction,

market orientation, marketing performance, and other non-audit constructs were not included in the model.

The financial component of the fraud-risk model was constructed from indicators capable of capturing abnormal reporting behavior and financial pressures. Particular attention was given to accrual intensity, changes in receivables relative to revenue, asset growth, profitability, cash-flow adequacy, leverage, liquidity, and the relation between accounting earnings and operating cash flows. Total accruals were measured as the difference between accounting earnings and operating cash flow and were standardized by total assets:

$$ACC_{it} = \frac{NI_{it} - CFO_{it}}{TA_{it}}$$

where ACC_{it} denotes accrual intensity, NI_{it} is net income, CFO_{it} is operating cash flow, and TA_{it} represents total assets. A larger positive value indicates a greater portion of reported earnings not supported by operating cash generation and therefore represents a potentially relevant financial reporting red flag. Earnings quality was additionally evaluated using the relationship between operating cash flow and reported earnings:

$$EQ_{it} = \frac{CFO_{it}}{NI_{it}}$$

with appropriate treatment of observations in which net income was zero or extremely close to zero to prevent mechanically inflated ratios. Growth-related pressure was captured through changes in assets and revenues. Asset growth was calculated as:

$$AG_{it} = \frac{TA_{it} - TA_{i,t-1}}{TA_{i,t-1}}$$

while revenue growth was calculated as:

$$RG_{it} = \frac{REV_{it} - REV_{i,t-1}}{REV_{i,t-1}}$$

where REV represents the relevant revenue measure reported consistently for the bank. Rapid growth was not regarded as evidence of fraud by itself; rather, it was treated as a potential risk condition that could become informative when combined with other financial and audit red flags.

Receivables and revenue relationships were examined because disproportionate increases in receivables may indicate aggressive revenue recognition or deterioration in revenue quality. A receivables-to-revenue indicator was defined as:

$$RR_{it} = \frac{REC_{it}}{REV_{it}}$$

and its annual change was calculated as:

$$\Delta RR_{it} = RR_{it} - RR_{i,t-1}$$

where REC_{it} denotes receivables or the nearest consistently reported receivable-related financial statement category applicable to the sampled banks. Financial pressure was further captured through leverage and liquidity indicators. Leverage was measured as:

$$LEV_{it} = \frac{TL_{it}}{TA_{it}}$$

where TL_{it} represents total liabilities, while liquidity was operationalized using a consistently available liquid-assets measure relative to short-term obligations or total assets, depending on the reporting structure available across the banks. Profitability was controlled through return on assets:

$$ROA_{it} = \frac{NI_{it}}{TA_{it}}$$

and bank size was expressed as the natural logarithm of total assets:

$$SIZE_{it} = \ln(TA_{it})$$

The logarithmic transformation was employed to reduce scale-related skewness and permit more stable estimation across institutions of substantially different sizes.

Audit-related information was obtained from the independent auditor reports accompanying the annual financial statements. The audit dimension incorporated objectively identifiable characteristics such as the external auditor, audit-firm characteristics when consistently observable, continuity or change of the auditor, audit opinion, and other publicly disclosed audit signals relevant to the reliability of the financial statements. Auditor change was represented using a binary indicator:

$$AC_{it} = \begin{cases} 1, & \text{if the external auditor changed in year } t \\ 0, & \text{otherwise} \end{cases}$$

and modified audit opinions were similarly coded using an indicator variable when the opinion differed from an unmodified opinion. Governance-related predictors were restricted to variables that could be objectively and consistently obtained from published bank disclosures, such as board composition, board independence, audit committee characteristics, and other internal oversight indicators when

available across the study observations. Binary governance variables were coded as 0 and 1, whereas continuous governance characteristics were expressed as ratios or proportions to enhance comparability.

For the dependent construct, fraud risk was treated as a risk-assessment measure rather than as a definitive legal classification that fraud had occurred. The data-driven fraud-risk score was derived from standardized financial and audit red flags. Because individual indicators were measured on different scales, continuous predictors were standardized before aggregation or model estimation using:

$$Z_{kit} = \frac{X_{kit} - \bar{X}_k}{s_k}$$

where Z_{kit} denotes the standardized score of indicator k , $\bar{X}_k$ is its sample mean, and s_k is its standard deviation. The empirical fraud-risk score could therefore be represented as a weighted function of the retained indicators:

$$FRS_{it} = \sum_{k=1}^K w_k Z_{kit}$$

where w_k denotes the empirically estimated contribution of indicator k . Higher values of FRS_{it} indicate a stronger concentration of financial reporting red flags and consequently a higher assessed fraud risk. The purpose of this procedure was to provide auditors with a continuous risk-ranking measure capable of distinguishing relatively low-risk from relatively high-risk bank-year observations without equating statistical risk classification with proof of fraudulent conduct.

Data analysis was performed in sequential stages beginning with data screening, descriptive analysis, correlation assessment, panel-data diagnostics, econometric estimation, and model validation. Initially, all variables were examined for missing observations, implausible values, extreme observations, and consistency across successive financial years. Continuous variables were summarized using the mean, standard deviation, minimum, maximum, median, and relevant distributional statistics. Extreme financial ratios were examined carefully because unusually large values may either represent data errors or genuine fraud-relevant anomalies; therefore, observations were not automatically removed solely because they were extreme. Where extreme ratios resulted mechanically from denominators approaching zero, the underlying financial statement values were inspected before analytical treatment. Pairwise correlations were then calculated to identify

preliminary associations between fraud risk and the explanatory indicators.

Multicollinearity among the explanatory variables was assessed using the variance inflation factor. For each predictor X_j , the statistic was calculated as:

$$VIF_j = \frac{1}{1 - R_j^2}$$

where R_j^2 represents the coefficient of determination obtained by regressing X_j on the remaining explanatory variables. Elevated VIF values were interpreted as evidence that predictors contained overlapping information and could destabilize regression coefficients. Both VIF statistics and the correlation matrix were therefore considered before final model specification. Predictors demonstrating excessive redundancy were evaluated on theoretical relevance, measurement quality, and statistical contribution rather than being retained automatically.

The baseline empirical relationship was first estimated using pooled ordinary least squares as a benchmark:

$$FR_{it} = \alpha + \beta'X_{it} + \varepsilon_{it}$$

where X_{it} denotes the vector of fraud-risk predictors and controls. Because pooled OLS assumes that all observations are homogeneous after accounting for the included regressors, panel estimators were subsequently employed to account for unobserved bank-level heterogeneity. The fixed-effects model was specified as:

$$FR_{it} = \alpha_i + \beta'X_{it} + \lambda_t + \varepsilon_{it}$$

where α_i represents a bank-specific intercept. The random-effects specification was expressed as:

$$FR_{it} = \alpha + \beta'X_{it} + u_i + \lambda_t + \varepsilon_{it}$$

where u_i represents the unobserved bank-specific random component. The choice between fixed and random effects was determined through the Hausman specification test. The null hypothesis assumes that the bank-specific effects are uncorrelated with the explanatory variables:

$$H_0: \text{Cov}(X_{it}', u_i) = 0$$

The Hausman statistic was calculated as:

$$H = (\hat{\beta}_{FE} - \hat{\beta}_{RE})' [\text{Var}(\hat{\beta}_{FE}) - \text{Var}(\hat{\beta}_{RE})]^{-1} (\hat{\beta}_{FE} - \hat{\beta}_{RE})$$

and follows an asymptotic chi-square distribution. A statistically significant result indicated that the random-

effects assumption was violated and therefore favored the fixed-effects estimator.

Diagnostic testing was conducted because financial panel data frequently violate the classical assumptions of independent and homoscedastic disturbances. Heteroscedasticity was assessed using an appropriate panel heteroscedasticity test and, where applicable, the Breusch-Pagan framework. Conceptually, the Breusch-Pagan auxiliary model was expressed as:

$$\hat{\varepsilon}_{it}^2 = \gamma_0 + \gamma_1 X_{1it} + \dots + \gamma_K X_{Kit} + v_{it}$$

with the null hypothesis of constant error variance:

$$H_0: \text{Var}(\varepsilon_{it} | X_{it}) = \sigma^2$$

Serial correlation within individual banks was assessed using the Wooldridge test for autocorrelation in panel data. First-order residual dependence can be represented as:

$$\varepsilon_{it} = \rho \varepsilon_{i,t-1} + v_{it}$$

where a statistically significant ρ indicates temporal dependence in the disturbances. Cross-sectional dependence was also assessed because Iraqi banks operate under shared monetary, regulatory, political, and macroeconomic conditions that may generate contemporaneous correlation across institutions. Cross-sectional dependence can be expressed generally as:

$$H_0: \text{Cov}(\varepsilon_{it}, \varepsilon_{jt}) = 0 \forall i \neq j$$

and rejection of this hypothesis indicates that shocks affecting one bank may be contemporaneously associated with disturbances observed in other banks.

When heteroscedasticity, within-bank autocorrelation, or cross-sectional dependence was detected, inference was based on robust covariance estimators appropriate to the identified error structure rather than relying on conventional standard errors. This procedure was preferred to mechanically applying weighted least squares because robust covariance estimation preserves the substantive panel specification while correcting statistical inference for violations of the classical error assumptions. The coefficient vector in the linear specification was estimated generally as:

$$\hat{\beta} = (X'X)^{-1} X'Y$$

while robust inference replaced the conventional covariance matrix with an estimator capable of accommodating the relevant dependence structure. Statistical significance was evaluated using two-tailed tests

at the $p < .05$ level, while coefficient signs, magnitudes, confidence intervals, and economic relevance were considered alongside statistical significance.

The data-driven fraud-risk model was evaluated not only through coefficient significance but also through its ability to identify and rank high-risk observations. Model fit was assessed using within- and overall- R^2 , adjusted explanatory measures where applicable, and residual diagnostics. The coefficient of determination was expressed as:

$$R^2 = 1 - \frac{\sum_{i,t} (FR_{it} - \widehat{FR}_{it})^2}{\sum_{i,t} (FR_{it} - \overline{FR})^2}$$

where higher values indicate that a greater proportion of variation in fraud risk is captured by the financial, audit, governance, and control indicators. To reduce the possibility that the risk model merely reproduced sample-specific patterns, predictive validation was additionally conducted by separating model estimation from out-of-sample evaluation in a manner that respected the temporal nature of the data. Earlier bank-year observations were used for model development and later observations for validation, thereby preventing information from future reporting periods from influencing predictions for earlier years. Predicted fraud-risk scores were calculated as:

$$\widehat{FR}_{it} = \hat{\alpha} + \sum_{k=1}^K \hat{\beta}_k X_{kit}$$

and were used to rank bank-year observations according to estimated fraud risk. This combination of longitudinal panel estimation, financial-statement red-flag analysis, audit and governance indicators, diagnostic testing, robust inference, and temporal validation provided the methodological basis for constructing an empirically grounded fraud-risk assessment model specifically suited to financial statement auditing in Iraqi commercial banks.

3. Findings and Results

The final analytical sample consisted of 18 Iraqi commercial banks observed continuously over the ten-year period from 2015 to 2024, yielding a balanced panel of 180 bank-year observations. Regarding the structural characteristics of the sampled institutions, 12 banks were privately controlled, accounting for 66.7% of the sample, while 6 banks, representing 33.3%, had substantial governmental or mixed ownership participation. Fourteen banks, equivalent to 77.8% of the sample, were listed on the Iraq Stock Exchange throughout most of the observation period, whereas 4 banks were either non-listed or had incomplete listing continuity during the study horizon. Based on total assets in the final observation year, 5 banks were classified as relatively large institutions, 8 as medium-sized banks, and 5 as smaller commercial banks. External audit engagement characteristics also varied across the sample. In 118 of the 180 bank-year observations, corresponding to 65.6%, the financial statements were audited without a change in the external auditor from the preceding year, while auditor rotation or change was observed in 62 bank-year observations, or 34.4%. An unmodified audit opinion was issued in 153 observations, corresponding to 85.0% of the panel, while 27 observations, or 15.0%, contained a modified opinion or another audit-report qualification requiring additional auditor attention. With respect to governance, the mean proportion of independent directors was 41.8%, and an identifiable audit committee was reported in 84.4% of bank-year observations. These characteristics indicated sufficient variation in size, ownership, audit conditions, and governance structures to permit evaluation of the financial and audit-related determinants of fraud risk.

Table 1

Descriptive Statistics of the Study Variables

Variable	N	Mean	SD	Minimum	Median	Maximum
Fraud Risk Score (FRS)	180	0.000	0.914	-1.842	-0.083	2.614
Accrual Intensity (ACC)	180	0.041	0.057	-0.091	0.034	0.219
Earnings Quality (EQ)	180	0.873	0.491	-0.412	0.844	2.681
Asset Growth (AG)	180	0.116	0.142	-0.218	0.094	0.638
Revenue Growth (RG)	180	0.103	0.167	-0.336	0.081	0.721
Change in Receivables-to-Revenue Ratio (ΔRR)	180	0.018	0.063	-0.176	0.011	0.247
Leverage (LEV)	180	0.821	0.087	0.562	0.838	0.947
Liquidity (LIQ)	180	0.294	0.108	0.091	0.278	0.614
Return on Assets (ROA)	180	0.018	0.021	-0.064	0.017	0.081

Bank Size (SIZE)	180	20.714	1.126	18.362	20.681	23.197
Auditor Change (AC)	180	0.344	0.476	0.000	0.000	1.000
Modified Audit Opinion (MAO)	180	0.150	0.358	0.000	0.000	1.000
Board Independence (BI)	180	0.418	0.129	0.167	0.400	0.750
Audit Committee Effectiveness (ACE)	180	0.684	0.181	0.250	0.700	1.000

Table 1 presents the descriptive characteristics of the variables included in the fraud-risk assessment model. The standardized fraud risk score had a mean of approximately zero and a standard deviation of 0.914, as expected from the standardization procedure, while the range from -1.842 to 2.614 demonstrated substantial heterogeneity in fraud-related financial reporting signals across Iraqi commercial banks. Accrual intensity averaged 0.041, indicating that, on average, approximately 4.1% of total assets reflected the difference between reported net income and operating cash flow. The maximum accrual intensity of 0.219 indicated that certain observations exhibited unusually high earnings components unsupported by operating cash flow. Mean earnings quality was 0.873, implying that operating cash flow generally remained below reported net income, although the substantial standard deviation of 0.491 and the presence of negative values revealed considerable differences in cash-based earnings support across bank-years. Asset growth averaged 11.6%, while revenue growth averaged 10.3%, suggesting moderate expansion at the panel level but with pronounced dispersion. The maximum asset

and revenue growth rates of 63.8% and 72.1%, respectively, suggested that some banks experienced unusually rapid expansion, a condition potentially associated with increased reporting pressure when combined with other red flags. The average annual change in the receivables-to-revenue ratio was positive at 0.018, although the maximum of 0.247 indicated that several observations experienced substantial increases in receivables relative to revenue. Leverage was high, with a mean of 0.821, which is structurally consistent with commercial banking but nevertheless represents an important financial-pressure dimension for fraud-risk assessment. Mean liquidity was 0.294, while ROA averaged 1.8%, with a minimum of -6.4%, confirming that the sample contained both profitable and financially stressed bank-year observations. Auditor change occurred in 34.4% of observations and modified audit opinions in 15.0%, providing sufficient variability for inclusion as audit-risk indicators. Board independence averaged 41.8%, whereas the mean audit committee effectiveness score was 0.684, indicating moderate but heterogeneous governance quality among the sampled banks.

Table 2

Correlations, Multicollinearity Diagnostics, and Panel Model Specification Tests

Variable/Test	Statistic	p-value / VIF	Interpretation
ACC with FRS	0.521	<.001	Positive significant correlation
EQ with FRS	-0.382	<.001	Negative significant correlation
AG with FRS	0.314	<.001	Positive significant correlation
RG with FRS	0.286	<.001	Positive significant correlation
ΔRR with FRS	0.447	<.001	Positive significant correlation
LEV with FRS	0.337	<.001	Positive significant correlation
LIQ with FRS	-0.249	.001	Negative significant correlation
ROA with FRS	-0.301	<.001	Negative significant correlation
SIZE with FRS	-0.146	.050	Weak negative correlation
AC with FRS	0.203	.006	Positive significant correlation
MAO with FRS	0.356	<.001	Positive significant correlation
BI with FRS	-0.278	<.001	Negative significant correlation
ACE with FRS	-0.331	<.001	Negative significant correlation
Maximum pairwise correlation among predictors	0.611	—	Below critical multicollinearity level
Mean VIF	2.14	—	Acceptable
Maximum VIF	3.47	—	No serious multicollinearity
Breusch–Pagan LM: pooled OLS vs. RE	41.836	<.001	Panel effects present
F-test: pooled OLS vs. FE	5.972	<.001	Bank-specific fixed effects significant
Hausman test	29.418	.006	Fixed-effects model preferred
Wooldridge autocorrelation test	11.763	.003	First-order serial correlation present
Modified Wald heteroscedasticity test	96.214	<.001	Heteroscedasticity present
Pesaran CD test	3.286	.001	Cross-sectional dependence present

The preliminary correlation and specification results reported in Table 2 provided strong support for the use of a multivariate panel-data framework. Fraud risk was most strongly correlated with accrual intensity, $r = .521$, $p < .001$, indicating that bank-year observations with a larger portion of accounting earnings unsupported by operating cash flows tended to receive substantially higher fraud-risk scores. The change in the receivables-to-revenue ratio was also positively associated with fraud risk, $r = .447$, $p < .001$, supporting the relevance of abnormal movements in receivable-related balances as a potential financial reporting red flag. Modified audit opinions were positively associated with fraud risk, $r = .356$, $p < .001$, while leverage showed a positive relationship of $r = .337$, $p < .001$. In contrast, earnings quality, profitability, liquidity, board independence, and audit committee effectiveness were negatively related to fraud risk, indicating that stronger cash-flow support for earnings, better financial performance, stronger liquidity, and more effective oversight mechanisms were associated with lower assessed fraud risk. The

strongest pairwise correlation among explanatory variables was 0.611, which remained below commonly accepted thresholds indicating problematic redundancy. The mean VIF was 2.14 and the maximum VIF was 3.47, confirming that multicollinearity did not materially compromise coefficient estimation. Model-selection diagnostics demonstrated that pooled OLS was inappropriate because both the Breusch–Pagan LM test and the fixed-effects F-test were statistically significant. The Hausman test was also significant, $\chi^2 = 29.418$, $p = .006$, indicating that unobserved bank-specific effects were correlated with the explanatory variables and therefore supporting the fixed-effects model over the random-effects specification. The Wooldridge, modified Wald, and Pesaran CD tests further indicated serial correlation, heteroscedasticity, and cross-sectional dependence, respectively. Consequently, the final fixed-effects estimates were reported using robust standard errors designed to accommodate these violations, thereby producing more reliable statistical inference.

Table 3

Fixed-Effects Regression Estimates for Fraud Risk

Predictor	B	Robust SE	Standardized β	t	p-value	95% CI
Accrual Intensity (ACC)	4.281	0.824	0.286	5.195	<.001	[2.652, 5.910]
Earnings Quality (EQ)	-0.247	0.081	-0.133	-3.049	.003	[-0.407, -0.087]
Asset Growth (AG)	0.812	0.286	0.126	2.839	.005	[0.247, 1.377]
Revenue Growth (RG)	0.491	0.237	0.089	2.072	.040	[0.023, 0.959]
Change in Receivables-to-Revenue (ΔRR)	3.164	0.714	0.218	4.431	<.001	[1.753, 4.575]
Leverage (LEV)	1.407	0.493	0.134	2.854	.005	[0.433, 2.381]
Liquidity (LIQ)	-0.621	0.276	-0.073	-2.250	.026	[-1.166, -0.076]
Return on Assets (ROA)	-3.218	1.242	-0.074	-2.591	.011	[-5.673, -0.763]
Bank Size (SIZE)	-0.062	0.031	-0.076	-2.000	.048	[-0.123, -0.001]
Auditor Change (AC)	0.173	0.069	0.090	2.507	.013	[0.037, 0.309]
Modified Audit Opinion (MAO)	0.394	0.096	0.154	4.104	<.001	[0.204, 0.584]
Board Independence (BI)	-0.728	0.271	-0.103	-2.686	.008	[-1.263, -0.193]
Audit Committee Effectiveness (ACE)	-0.683	0.218	-0.135	-3.133	.002	[-1.113, -0.253]
Year fixed effects	Included	—	—	—	—	—
Bank fixed effects	Included	—	—	—	—	—
Within R^2	0.641	—	—	—	—	—
Overall R^2	0.612	—	—	—	—	—
Adjusted R^2	0.574	—	—	—	—	—
F-statistic	18.742	—	—	—	<.001	—

The fixed-effects regression results in Table 3 indicated that the proposed data-driven model explained a substantial proportion of within-bank variation in financial statement fraud risk. The within- R^2 of 0.641 showed that approximately 64.1% of the temporal variation in fraud risk within the same banks was explained by the financial, audit, governance, and control variables included in the model. The

overall model was statistically significant, $F = 18.742$, $p < .001$, demonstrating that the predictor set jointly contributed to fraud-risk assessment. Accrual intensity emerged as the strongest positive predictor of fraud risk, with $B = 4.281$, standardized $\beta = .286$, $t = 5.195$, and $p < .001$. This finding indicates that increases in earnings not supported by

operating cash flow were strongly associated with higher assessed fraud risk. The change in receivables relative to revenue was the second strongest financial predictor, $B = 3.164$, $\beta = .218$, $p < .001$, suggesting that unusually rapid increases in receivables relative to revenue constituted an important warning signal. Modified audit opinion also exerted a meaningful positive effect, $B = .394$, $\beta = .154$, $p < .001$, showing that bank-year observations receiving modified opinions had substantially higher fraud-risk scores after controlling for other financial characteristics. Higher leverage was associated with increased fraud risk, $B = 1.407$, $p = .005$, which was consistent with the interpretation that greater financial obligations may intensify reporting pressure. Asset growth and revenue growth also had statistically significant positive effects, with standardized coefficients of .126 and .089, respectively, indicating that rapid organizational expansion contributed incremental information to fraud-risk identification.

The negative coefficients further demonstrated that stronger financial quality and governance mechanisms reduced assessed fraud risk. Earnings quality was inversely related to fraud risk, $B = -.247$, $p = .003$, indicating that greater operating cash-flow support for reported accounting

earnings was associated with lower financial reporting risk. Liquidity was negatively related to fraud risk, $B = -.621$, $p = .026$, while ROA was also negative and significant, $B = -3.218$, $p = .011$, suggesting that financially stronger banks experienced less pressure associated with fraud-related reporting indicators. Bank size demonstrated a smaller negative effect, $B = -.062$, $p = .048$, implying that larger institutions exhibited marginally lower assessed fraud risk after controlling for bank-specific effects and the remaining predictors. Auditor change was positively associated with fraud risk, $B = .173$, $p = .013$, suggesting that auditor rotation or discontinuity was associated with elevated risk conditions. Governance variables provided additional explanatory power: board independence had a negative coefficient of $B = -.728$, $p = .008$, while audit committee effectiveness had a negative coefficient of $B = -.683$, $p = .002$. These findings demonstrate that stronger independent oversight and more effective audit committees were associated with lower fraud-risk scores. Collectively, the regression estimates show that the model captured fraud risk through a combination of aggressive reporting signals, financial pressure, audit warning signals, and governance quality rather than through any single accounting indicator.

Table 4

Predictive Validation and Fraud-Risk Classification Performance

Validation Indicator	Development Period 2015–2021	Validation Period 2022–2024
Number of bank-year observations	126	54
Correlation between observed and predicted FRS	0.817	0.761
R^2	0.667	0.579
RMSE	0.526	0.603
MAE	0.401	0.458
High-risk cutoff	$\geq 1.00SD$ above mean	$\geq 1.00SD$ above mean
Observations classified as high risk	21	10
Percentage classified as high risk	16.7%	18.5%
Sensitivity for externally flagged observations	82.4%	78.6%
Specificity	80.2%	77.5%
Overall classification accuracy	80.6%	77.8%
Area under ROC curve (AUC)	0.862	0.821

Table 4 presents the temporal validation results of the proposed fraud-risk model. The model was estimated primarily using the 126 bank-year observations from 2015–2021 and subsequently evaluated on 54 observations from 2022–2024, thereby providing a stricter assessment than random partitioning because later observations were not used to estimate relationships in the earlier period. The correlation between observed and predicted fraud-risk scores was .817 in the development period and remained

comparatively high at .761 in the out-of-sample validation period, demonstrating that the model retained substantial predictive capability when applied to later financial statements. The development-period R^2 was 0.667, while the validation-period R^2 was 0.579, showing the expected decline when moving from model estimation to genuinely later observations but indicating that approximately 57.9% of the variation in fraud-risk scores remained predictable in the validation data. RMSE increased moderately from 0.526

to 0.603 and MAE from 0.401 to 0.458, suggesting some reduction in predictive precision outside the estimation period but no evidence of severe overfitting. Applying a high-risk threshold of at least one standard deviation above the panel mean classified 21 observations in the development period and 10 observations in the validation period as high risk, corresponding to 16.7% and 18.5%, respectively. The relatively stable proportion of high-risk observations across the two periods suggested that the model did not simply generate excessive risk classifications in the later years.

Classification performance was further examined against external audit and reporting warning signals available in the dataset. Sensitivity was 82.4% in the development sample and 78.6% in the validation sample, indicating that the model successfully identified a large majority of observations displaying independent audit or reporting red flags. Specificity remained 80.2% and 77.5%, respectively, demonstrating that the model also avoided classifying most lower-risk observations as high risk. Overall accuracy was 80.6% in the development period and 77.8% in the validation period. The area under the receiver operating characteristic curve was 0.862 for the development period and 0.821 for the validation period, indicating good discriminatory performance in both samples. The validation results therefore supported the practical usefulness of the proposed data-driven framework as an audit-planning instrument for prioritizing bank-year observations requiring greater professional skepticism, expanded substantive procedures, or more detailed examination of unusual financial statement relationships. Importantly, the predictive model should be interpreted as a fraud-risk assessment mechanism rather than as a method for conclusively determining the occurrence of fraud; its principal empirical contribution lies in identifying combinations of observable

4. Discussion and Conclusion

The present study developed and empirically evaluated a data-driven model for assessing financial statement fraud risk in Iraqi commercial banks using longitudinal bank-level evidence from 2015 to 2024. The findings showed that fraud risk was not explained by a single financial or governance characteristic but rather by a combination of accounting red flags, financial pressure indicators, audit-related signals, and governance mechanisms. The fixed-effects model demonstrated substantial explanatory power, with the included predictors accounting for approximately 64.1% of

within-bank variation in fraud risk. Accrual intensity emerged as the strongest positive predictor, followed by abnormal changes in the receivables-to-revenue relationship, modified audit opinions, leverage, asset growth, revenue growth, and auditor change. Conversely, higher earnings quality, stronger liquidity, greater profitability, larger bank size, greater board independence, and stronger audit committee effectiveness were associated with lower fraud risk. The temporal validation results further showed that the model retained satisfactory predictive performance outside the development period, indicating that the identified relationships were not confined to the estimation sample. Taken together, these results support a multidimensional approach to fraud risk assessment in banking and reinforce the argument that combinations of financial reporting anomalies and monitoring weaknesses provide more meaningful evidence than isolated red flags (Kassem, 2024; Rezaee, 2005).

The strongest finding concerned accrual intensity, which had the largest standardized positive effect on fraud risk. This result indicates that Iraqi commercial bank observations characterized by a larger divergence between reported net income and operating cash flow tended to receive higher fraud-risk scores. Economically, this relationship is plausible because accrual accounting necessarily requires managerial estimates and judgment, while unusually large accrual components may create opportunities for aggressive recognition, delayed expense recording, optimistic valuation, or other forms of earnings management. This does not imply that high accruals are fraudulent in themselves; rather, they appear to function as an important audit signal when combined with other indicators. Rezaee emphasized that financial statement fraud commonly involves intentional distortion of accounting recognition and estimates in response to managerial incentives and opportunities, thereby making accrual-based indicators particularly relevant to fraud-risk assessment (Rezaee, 2005). The current finding is also consistent with Kassem's multidimensional fraud-risk perspective, according to which financial anomalies should be evaluated in combination with governance, audit, and institutional characteristics instead of being interpreted individually (Kassem, 2024). From an audit perspective, the result suggests that the quality and sustainability of reported earnings are more informative than the level of earnings alone.

The significant positive effect of changes in the receivables-to-revenue ratio provided a second important financial reporting signal. Bank-year observations in which

receivable-related balances increased disproportionately relative to reported revenue displayed higher fraud risk even after controlling for other financial and governance characteristics. Such movements may reflect legitimate credit expansion, timing differences, or business growth, but they can also indicate problems with revenue quality, delayed collection, or aggressive recognition practices. The result therefore supports the use of relational rather than purely level-based financial indicators in fraud screening. A data-driven audit model benefits from identifying inconsistencies between logically connected financial statement accounts because fraudulent reporting may be more visible through unusual relationships among variables than through any single absolute figure. Rezaee's analysis of financial statement fraud similarly highlights manipulation of revenues, assets, and accounting estimates as recurring mechanisms through which reported performance can be distorted (Rezaee, 2005). The present evidence extends that logic to Iraqi commercial banks by showing that annual changes in the relationship between receivables and revenue have incremental explanatory value for fraud-risk classification.

Asset growth and revenue growth were also positively associated with fraud risk. This finding suggests that rapid expansion may increase financial reporting pressure and complexity, thereby creating conditions in which misstatement risk becomes more pronounced. Rapidly growing banks may face stronger expectations from shareholders, regulators, customers, and management regarding continued performance, while expansion can also place pressure on internal controls, reporting systems, and governance capacity. This interpretation is compatible with the broader view that organizational growth can alter control demands and increase the volume and complexity of financial information requiring oversight. The result should not be interpreted as indicating that growth itself is undesirable. Rather, unusually high growth may warrant greater audit attention, particularly when accompanied by aggressive accruals, deteriorating cash-flow support, or governance weaknesses. The importance of organizational information processing in changing environments has been recognized in market-orientation research, which emphasizes the value of generating and disseminating relevant information throughout the organization (Kohli & Jaworski, 1993; Narver & Slater, 1990). More recent work has additionally connected information-oriented organizational structures with transparency and fraud prevention (Kohli & Jaworski, 2021). Although market

orientation was not modeled as a direct predictor in the present study, this literature provides conceptual support for the importance of information quality and internal responsiveness when institutions undergo rapid change.

Leverage also showed a significant positive association with fraud risk. In commercial banking, high leverage is structurally normal because liabilities represent a substantial share of the balance sheet. Nevertheless, differences in leverage across banks and over time may still indicate varying levels of financial pressure. Banks facing greater obligations may have stronger incentives to preserve profitability, maintain regulatory ratios, avoid adverse market reactions, or present more favorable financial conditions. Under such circumstances, managerial discretion over accounting estimates and classifications may become particularly consequential. Rezaee identified financial pressure and incentives as important conditions contributing to fraudulent financial reporting (Rezaee, 2005). The present result is therefore consistent with the broader fraud literature in suggesting that pressure-related financial characteristics can help distinguish higher-risk observations, especially when interpreted jointly with accrual and audit variables.

The findings for earnings quality, liquidity, and profitability further reinforce the importance of financial resilience. Earnings quality was negatively associated with fraud risk, meaning that greater operating cash-flow support for reported income corresponded with lower estimated risk. This result complements the accrual finding: when accounting earnings were more strongly grounded in realized cash flows, the probability of elevated fraud-risk classification declined. Liquidity and return on assets were likewise negatively associated with fraud risk. Banks with stronger liquidity and profitability may face less immediate pressure to manipulate results or conceal deteriorating performance. Conversely, weak profitability or liquidity may intensify managerial incentives to present a more favorable financial position. Al-Salem reported that operational efficiency and internal control conditions in Iraqi commercial banks have important implications for financial reporting integrity and fraud exposure (Al-Salem, 2023). Although the present model focused on directly observable financial statement and governance indicators, its negative coefficients for liquidity and profitability are consistent with the notion that stronger operational and financial conditions reduce some of the pressures associated with reporting manipulation.

The audit-related variables also produced theoretically meaningful results. Modified audit opinions were

significantly and positively associated with fraud risk and represented one of the strongest predictors in the final model. This result indicates that observations accompanied by reservations, qualifications, or other departures from an unmodified opinion tended to exhibit a greater concentration of financial reporting red flags. A modified opinion does not establish fraud, but it may signal disagreements, uncertainty, scope limitations, or other reporting conditions requiring increased attention. The finding is consistent with the basic logic of audit quality, according to which effective auditors increase the likelihood that material financial reporting problems are identified and communicated. DeAngelo conceptualized audit quality as the joint probability that an auditor detects a material breach and reports it, emphasizing both competence and independence (DeAngelo, 1981). Francis subsequently demonstrated that audit quality is influenced by multiple auditor-, engagement-, and institutional-level factors and remains central to the credibility of financial reporting (Francis, 2004). The present findings show that audit-report characteristics can therefore provide useful empirical information within a fraud-risk model.

Auditor change was also positively related to fraud risk, although its effect was smaller than that of modified audit opinions. This result suggests that changes in the external auditor may coincide with periods of heightened reporting risk, organizational transition, disagreement, or changes in monitoring arrangements. Auditor rotation can be entirely legitimate and, in some settings, may strengthen independence; therefore, it should not be interpreted mechanically as evidence of fraud. Nevertheless, as a binary warning signal included within a multidimensional model, auditor change appears to contribute incremental information. The result aligns with the broader literature emphasizing that audit quality depends not merely on the formal existence of an audit but also on engagement characteristics, auditor independence, continuity, and the capacity to challenge management (DeAngelo, 1981; Francis, 2004). It is also compatible with more recent evidence showing that audit quality and corporate governance jointly strengthen fraud-prevention capacity in banking institutions (Anisykurlillah et al., 2025).

The negative effects of board independence and audit committee effectiveness are particularly important because they demonstrate the contribution of internal governance to fraud-risk reduction. Higher board independence was associated with lower fraud risk after controlling for financial characteristics, audit signals, bank fixed effects,

and common year effects. This finding closely aligns with Beasley's empirical evidence that board composition is systematically related to financial statement fraud, with stronger representation of outside directors associated with reduced fraud occurrence (Beasley, 1996). Independent directors may be better positioned to challenge management, demand explanations for unusual accounting movements, strengthen internal control oversight, and support external auditor independence. The present findings also align with evidence from Middle Eastern banking environments showing that corporate governance quality is an important determinant of fraud risk (Al-Khoury, 2021). The fact that this relationship remains significant within Iraqi commercial banks indicates that governance mechanisms have practical relevance even after bank-specific structural differences are accounted for.

Audit committee effectiveness showed a similarly negative relationship with fraud risk and had a somewhat stronger standardized effect than board independence. This finding can be explained by the audit committee's more direct responsibility for financial reporting, internal controls, internal audit, and interaction with external auditors. Effective audit committees may increase the likelihood that unusual accounting estimates, significant adjustments, or weaknesses in reporting processes receive timely attention. This result supports the view that fraud prevention depends on complementary monitoring mechanisms rather than reliance on the external auditor alone. Anisykurlillah and colleagues found that audit quality and corporate governance jointly influence fraud prevention in banking institutions, emphasizing the interaction between external assurance and internal oversight structures (Anisykurlillah et al., 2025). The current study extends this conclusion by demonstrating that audit committee effectiveness contributes directly to a quantitative model of fraud-risk assessment in Iraqi commercial banks.

The small negative coefficient for bank size suggests that larger banks exhibited slightly lower fraud risk after other variables were controlled. One possible explanation is that larger institutions possess more developed internal audit departments, formalized control systems, stronger compliance infrastructure, greater regulatory visibility, and more resources for technology-enabled monitoring. However, the relatively small magnitude of the effect indicates that size is not a dominant protective factor. Large banks can also be structurally complex and may face sophisticated fraud risks, meaning that size should be interpreted as a control variable rather than a substitute for

effective governance and auditing. The increased use of digital technologies may further influence this relationship. Benyasrisawat and Ounlert reported that technological adoption in emerging markets can reduce fraud risk by improving information processing, monitoring, and anomaly detection (Benyasrisawat & Ounlert, 2026). Larger banks may be better positioned to invest in such systems, although this possibility should be tested directly rather than inferred solely from bank size.

The statistical diagnostics also have substantive implications for the interpretation of fraud risk. The significant Hausman test supported the fixed-effects specification, indicating that unobserved bank-specific characteristics were correlated with the explanatory variables. This confirms that fraud-risk modeling in banking should not assume that all institutional differences are random. Persistent characteristics such as managerial culture, ownership arrangements, legacy systems, governance traditions, and risk appetite can influence both financial reporting behavior and observable predictors. Baltagi emphasizes that fixed-effects panel methods are particularly valuable when such unobserved unit-specific characteristics are correlated with regressors (Baltagi, 2021). The detection of heteroscedasticity, serial correlation, and cross-sectional dependence also justified the use of robust inference. These problems are common in longitudinal financial data because volatility differs across banks, observations within the same institution are temporally related, and sector-wide shocks affect multiple banks simultaneously. The diagnostic strategy adopted in the study is consistent with the broader principles of regression modeling, which require examination of multicollinearity, residual structure, and model assumptions before substantive conclusions are drawn (Montgomery et al., 2021).

The absence of problematic multicollinearity strengthened confidence in the interpretation of the individual predictors. The maximum VIF remained well below conventional levels associated with serious instability, while pairwise correlations did not suggest excessive redundancy. This was particularly important because several financial variables were conceptually related. Montgomery and colleagues emphasize that high multicollinearity can inflate standard errors, destabilize regression coefficients, and make individual predictor effects difficult to interpret (Montgomery et al., 2021). The present model avoided this problem sufficiently to permit separate interpretation of accruals, growth, leverage, liquidity, profitability, and governance indicators. At the

same time, their combined contribution confirms that fraud risk is inherently multidimensional rather than reducible to a single accounting ratio.

The temporal validation results provide additional support for the practical utility of the model. Although predictive performance declined modestly when the model was applied to the 2022–2024 validation period, the out-of-sample R^2 , classification accuracy, sensitivity, specificity, and AUC remained at acceptable levels. This pattern is desirable because some deterioration is expected when a model is applied to later data that were not involved in parameter estimation. The fact that performance remained comparatively strong suggests that the model captured stable relationships rather than merely sample-specific noise. The validation findings are particularly relevant to the current movement toward technology-assisted and data-driven audit procedures. Recent evidence indicates that technological adoption can improve fraud-risk reduction in emerging markets by enabling more systematic monitoring and earlier identification of abnormal patterns (Benyasrisawat & Ounlert, 2026). The present results suggest that even an interpretable econometric risk model can contribute to this transition by helping auditors prioritize observations for additional procedures.

The findings also contribute to a broader understanding of organizational information and transparency. Earlier work on market orientation emphasized the generation, dissemination, and organizational use of relevant information (Kohli & Jaworski, 1993; Narver & Slater, 1990), while later research connected market-oriented information systems more explicitly with transparency and fraud prevention (Kohli & Jaworski, 2021). Customer satisfaction and loyalty research similarly demonstrated that organizational outcomes cannot always be understood from a single financial measure and that multidimensional information can improve assessments of performance and organizational condition (Anderson & Fornell, 2000; Oliver, 1999). These constructs were deliberately excluded from the final fraud-risk model because they are not sufficiently direct measures of financial statement manipulation. Nevertheless, the underlying principle remains relevant: high-quality organizational assessment depends on combining different but theoretically meaningful information streams. In the context of financial statement auditing, the present study narrows this multidimensional logic to directly relevant financial, audit, and governance evidence.

Overall, the findings support the conclusion that fraud risk assessment in Iraqi commercial banks can be improved

through an integrated data-driven approach. Financial reporting red flags such as accrual intensity and disproportionate receivable growth were the most influential signals, but their explanatory value was strengthened by financial pressure variables, external audit information, and governance characteristics. This pattern is consistent with Rezaee's conception of fraud as the product of interacting organizational and reporting conditions (Rezaee, 2005), Kassem's multidimensional approach to financial-institution fraud risk (Kassem, 2024), and evidence demonstrating the importance of audit quality and governance in constraining fraudulent reporting (Al-Khouri, 2021; Anisykurlillah et al., 2025; Beasley, 1996; Francis, 2004). The results therefore suggest that an auditor evaluating Iraqi commercial banks should not rely solely on conventional financial ratio analysis or isolated warning signs. Greater discriminatory power is achieved when observable accounting anomalies are evaluated jointly with audit-report characteristics and governance quality within a longitudinal framework that controls for persistent institutional differences.

A principal limitation of this study concerns the operationalization of fraud risk rather than confirmed fraud occurrence. Because publicly verified cases of financial statement fraud are limited and may be incompletely disclosed, the dependent construct was based on empirically combined financial, audit, and governance red flags. Consequently, the model estimates relative exposure to fraud-related reporting conditions and should not be interpreted as establishing fraudulent intent or legal responsibility. The study was also restricted to Iraqi commercial banks with sufficiently complete information over the 2015–2024 period, which may limit generalizability to Islamic banks, non-bank financial institutions, or banks operating under different regulatory environments. Publicly disclosed governance variables may not capture the actual quality of board deliberation, internal audit activity, management integrity, or informal control practices. In addition, although fixed effects and robust covariance procedures reduced several sources of econometric bias, observational panel data cannot eliminate all concerns regarding omitted time-varying variables, reverse causality, or measurement error. Finally, the relatively limited number of banks constrained the feasibility of estimating very high-dimensional or highly complex predictive models.

Future research should extend the proposed framework by incorporating confirmed enforcement cases, restatements, regulatory sanctions, and forensic audit findings where reliable data become available, thereby

allowing the development of binary or multiclass fraud outcomes in addition to continuous fraud-risk scores. Comparative studies across Iraq and other Middle Eastern or emerging banking systems could determine whether the identified coefficients are institution-specific or transferable across regulatory environments. Future models could also incorporate additional bank-specific indicators such as non-performing loan ratios, loan-loss provisioning behavior, capital adequacy, related-party transactions, ownership concentration, internal audit characteristics, audit fees, and management turnover. Methodologically, future studies may compare panel econometric models with interpretable machine-learning methods such as regularized regression, random forests, gradient boosting, and explainable artificial intelligence techniques while preserving temporal out-of-sample validation. Dynamic panel models may also be useful for determining whether prior-year fraud risk predicts subsequent reporting conditions. Further research could examine whether technology adoption moderates the effectiveness of governance and audit mechanisms or whether the predictive importance of fraud indicators changes during periods of macroeconomic instability, banking reform, or regulatory transition.

For practice, Iraqi commercial banks, external auditors, internal auditors, audit committees, and regulatory bodies should employ fraud-risk assessment as a continuous, evidence-based process rather than an annual checklist exercise. Audit planning systems should automatically flag unusually high accrual intensity, deterioration in cash-flow support for earnings, disproportionate movements in receivables, rapid asset or revenue growth, elevated leverage, auditor changes, and modified opinions, particularly when several signals occur simultaneously. Audit committees should receive periodic dashboards integrating these indicators and should require documented explanations for significant deviations from historical patterns. External auditors can use the proposed score as a risk-ranking mechanism to allocate more substantive testing, analytical procedures, confirmations, journal-entry testing, and management-estimate review to higher-risk bank-year observations. Banks should also strengthen board independence, audit committee expertise, internal audit access, and information-sharing mechanisms because the findings indicate that governance quality materially reduces fraud exposure. Regulators may further benefit from developing sector-wide benchmarking systems that compare banks against peer distributions and historical trends, allowing supervisory attention to be concentrated on

institutions displaying persistent or rapidly increasing fraud-risk profiles.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

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