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Differential Predictors of Financial Distress in Listed Versus Unlisted Indian Firms: A Machine Learning Approach

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Abstract

This study identifies the key determinants of financial distress and evaluates alternative prediction models for both listed and unlisted firms in India. It uses financial data from 1,473 NSE-listed and 472 unlisted Indian firms (2010–2023). Six firm characteristics – profitability, liquidity, solvency, capital structure, operating efficiency, and size – are measured using financial ratios, with market performance additionally included for listed firms. Feature selection identifies the best ratio per characteristic. Classical logit and multiple machine learning models are compared for distress prediction. It is found that leverage, firm size, and capital structure are significant predictors for both firm types. However, optimal measures differ: listed firms are better captured by ROA, working capital to total assets, and sales to total assets, whereas net profit margin, current ratio, and debt collection period perform better for unlisted firms. Machine learning models outperform the logit model, with Random Forest emerging as the best predictor. The study is among the first to simultaneously cover both listed and unlisted Indian firms and to apply machine learning for identifying distress determinants as well as prediction, moving beyond classical statistical approaches. However, the study is limited only to Indian market data, hence restricting cross-market generalisation. Future research should extend to additional emerging markets and more advanced modelling architectures. The findings of the study offer key insights for policy-makers and regulators in designing early-warning frameworks, for commercial banks – in credit risk assessment, for corporate management – in financial monitoring, and for academics – in advancing distress modelling methodology.

Keywords: financial distress, listed and unlisted companies, comparative performance, logit model, machine learning models, feature selection, entropy

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Introduction

Predicting the financial health of any company has always been a conundrum for the stakeholders. Prior research investigates the possibilities of financial distress and the causative factors over the past century, especially since the great depression of 1929. The first recognized article was published in the Bureau of Business Research in 1930 [1], followed by [2–27]. All of them used financial ratios and other micro-level specific characteristics for determining the level of financial distress, whereas [28–37] used financial ratios especially in country-specific environments as determinants of financial distress.

Corporate failure prediction models ranged from univariate financial ratio analysis to multivariate analysis and from discriminant models to logit models [38], whereas [39] used artificial neural networks (ANN); [40] – a simple hazard model; [41] – support vector machines (SVM); [42] – data envelopment analysis (DEA); [43] – the combination of principle component analysis and SVM; and [44] – binary regression accounting-based model. Using the logit model, ANN, SVM, Partial Least Squares (PLS), and a hybrid model integrating SVM with PLS, [45] predicted financial distress for small and medium French companies. [46–47] employed deep learning models using textual disclosures; [48] used the ant colony optimization technique; [49] applied transactional data and two-stage multi-objective feature selection; [50] use the binomial logit model along with ANN and SVM for predicting financial distress. [51] developed a firm's distress and recovery prediction score by using both logit regressions and machine learning techniques, whereas [52] used a hybrid multi-layer perceptron ANN with the traditional Altman *Z*-Score model for predicting financial distress, and observed that the hybrid model was superior to the traditional Altman *Z*-Score and pure ANN models. [53] proposed a Malmquist DEA based on a multi-period performance evaluation framework, whereas [54] use a modified Z-score model for developing the Troubled Debt Restructuring probability index for distressed and non-distressed firms based on the logistic regression model. [55] used the interest coverage ratio (ICR) and the return on assets (ROA) for determining financial distress and found that generalized extreme value regression with and without the feature selection provides the best prediction for financial distress. [56] conducted a comprehensive survey, classification, and critical analysis of the literature on corporate bankruptcy and financial distress predictions. [57] employs several models, including the Altman model (Z-Score), the Springate model (S-Score), the Zmijewski model (X-Score), the Grover model (G-Score), and the Taffler model to predict financial distress and corporate bankruptcy. Out of these, the Taffler model emerged as superior to the rest. [58] applied machine learning techniques for the default prediction in unlisted micro, small, and mid-sized enterprises (MSME) in Italy. They used a public – private firm mapping approach with an objective to improve the default predictions for private unlisted firms, and found that prediction quality significantly improved. Thus, they concluded that noisy accounting information hinders accurate prediction of default in unlisted companies.

Early and accurate detection of any possibility of financial distress is an extremely important theme in corporate finance research. However, after reviewing the literature, the following gaps have been identified. First, prior research is mostly focused on mature markets. Similar work for emerging markets like India is limited, although it is highly relevant given the growing contribution of such markets to the world economy. Secondly, most of the studies have used traditional multivariate techniques for identifying the determinants of financial distress. Only a few recent studies have applied modern machine learning approaches for variable selection as well as model estimation. Finally, the studies are confined to large and listed companies except a few [44; 45], which examine this issue in small and medium enterprises in the unlisted sample. It may be noted that financial distress, especially during the crisis period such as the COVID-19 pandemic, is likely to be more pronounced for unlisted companies compared to large listed companies, which have more resilient balance sheets. The primary motivation of the present study is to fill these important gaps in past research.

The present study focuses on financial distress modeling and prediction for India, which is the fastest-growing large emerging market. India is the 3rd largest world economy in terms of purchasing power parity and hosts the 4th largest capital market in the world in capitalization terms.

Given the growing stature of India on the world stage, the study of financial distress becomes extremely pertinent for global lending agencies, credit rating firms, investors, and funds. Findings related to India can also be used to draw some general conclusions about distress prediction for other emerging markets.

Furthermore, the present research adopts a fully machine learning-based approach for identifying determinants as well as model estimation. It also attempts to predict financial distress for both the listed and the unlisted samples of Indian companies by using machine learning tools for both variable selection and model estimation. It also draws important conclusions about the role and relative importance of the factors and efficacy of alternative machine learning models for the two samples. The comparative analysis shall provide academicians and practitioners with important insights about model construction based on the nature of the corporate sector.

More specifically, this study attempts to identify the financial ratios that have relatively higher predictive power for diagnosing the financial health of Indian corporations, both listed and unlisted. Financial distress is measured using three financial variables: ICR, changes in equity, and changes in total assets. This three-way accounting-based definition of distress is adapted from the work of [59; 60].

The study assesses the predictive ability of the traditional binomial logit model and selected machine learning-based models, namely SVM, ANN, Random Forest (RF), and Gradient Boost (GB). The study also compares the accuracy of one-year and two-year ahead forecasts.

Table 1. Key determinants of financial distress used in the study

We use several firm characteristics for financial distress prediction. Key financial ratios along with their measures used to represent each characteristic are listed in this table.

Characteristics	Ratio	Measures	Characteristics	Ratio	Measures
Profitability	Net Profit Margin (NPM)	Net Profit/Net sale	Operating efficiency (Activity)	Debtor Days(DD)	(Debtors/Operating Revenue)*360
	Gross Profit Margin (GPM)	Gross Profit/Net sale		Asset Turnover ratio (ATR)	Sales Revenue/Total Assets
	Return on Net Worth (RONW)	Net Profit/Shareholders fund		Stock Turnover Ratio (STR)	Operating Revenue/Stock
	Return on Capital Employed (ROCE)	Net Profit/Capital Employed	Solvency	Financial Leverage (FL)	Long-term Liabilities/Total Assets
	Return on Asset (ROA)	Net Profit/Total Asset		Gearing Ratio (GR)	Long-term Liabilities/Capital Employed
Liquidity	Quick Ratio (QR)	Quick Assets/Current Liabilities (QA/CL)		Debt ratio (DR)	Total Debt/Total Assets
	Current Ratio (CR)	Current Assets/Current Liabilities (CA/CL)		Solvency Ratio (SR)	(PAT + Depreciation)/(Long Term liabilities+ Short Term Liabilities)
	NCI	(QA – CL)/Daily Operating Expenses		Repayment Capacity (RC)	Financial Debt/Cash flow
	CFO/TL	Total Cash from Operation/ Total Liabilities		DE	Debt/Equity
	CF/TA	Cash flow/Total Assets		RE/TA	Retained Earnings/Total Assets
	CF/OR	Cash flow/Operating Revenue	Size	Ln(TA)	Ln (Total Assets)
	WC/TA	Working Capital/Total Assets	Market Value	P/E	Market Price per share/ Earning per share
Structure	Eq/TA	Equity/Total Assets		P/B	Market Price per share/Book Value per share
	CA/TA	Current Assets/Total Assets			
	CL/TL	Current Liabilities/ Total Liabilities			
	FA/TA	Fixed Assets/Total Assets			
	SF/NCL	Shareholders' Funds/Non Current Liabilities			

We provide mean financial ratios for total, healthy and distressed firms for listed and unlisted sample companies.

We pursue the following research objectives: i) Identify principal determinants as well as optimal technique for predicting financial distress in the Indian listed company sample; ii) Determine the factors and the best modeling techniques for unlisted Indian companies; and iii) Compare and contrast the findings for listed and unlisted samples and draw key managerial implications.

The remaining part of the study is organized as follows: Second section presents data and variable construction whereas methodology and estimation procedures are discussed in third section. The empirical results and discussion are provided in fourth section, while fifth section contains conclusions and managerial implications.

Data and Variable Measurement

Data

The study originally considered **2730 listed companies** from the National Stock Exchange of India from 2010 to 2023 and **38628 unlisted companies** from 2010 to 2022**,** using data collected from the Ace Equity database. Applying the filter rule of at least 80% availability of financial ratios and followed by dropping the financial companies (based on the Global Industry Classification Standard) as they have unique operating, financial, and risk characteristics [61], the number of listed companies ranged from **1091** to **1149** during the period of study, resulting in **14,607 firm-year** observations. Similarly, the number of unlisted companies in the sample ranged from **340 to 472** per year, which resulted in **5176 firm-year** observations.

Variable Measurement

Taking clues from prior literature on financial distress [45; 60; 62; 63], the study employs 30 financial ratios, comprising 28 accounting and 2 market-based ratios as independent variables for empirical analysis. These financial ratios satisfy our filter rule as their information is available for at least 80% of evaluated cases. The accounting ratios are used to measure six important firm characteristics: profitability, liquidity, structure, operating efficiency, solvency and size. The number of ratios representing profitability are five; liquidity – seven; structure – five; operating efficiency (activity) – three; and solvency – seven; Firm size is measured by the natural log of total assets in the study. The two market-based ratios are market price per share to earnings per share (P/E ratio) and market price per share to book value per share (P/B ratio). However, only 28 financial ratios are used for unlisted firms owing to non-availability of market variables for such companies (Table 1).

The study uses three financial indicators, namely, ICR defined as EBITDA (Earnings Before Interest, Tax, Depreciation, and Amortization) divided by the interest charge; change in the market value of equity (Del EQ); and change in the value of total assets (Del TA) for classifying the firms as healthy or distressed. ICR shows the firm's capacity to meet its fixed financial obligations. Higher ICR implies that the firm is expected to be in good health, while its lower value is an indicator of corporate distress. A healthy firm shall also experience an increase in equity value owing to positive expectations of investors. In contrast, perceived financial distress results in negative investor sentiments, causing the equity value to decline. Finally, any decline in asset value shall imply corporate contraction and reduce the firm's capacity to meet its debt obligations. We assume that healthy companies will meet all three criteria i.e., i) ICR greater than or equal to 1; ii) Del EQ with respect to the previous year greater than or equal to 0; iii) Del TA with respect to previous year greater than or equal to 0. Companies having ICR less than 1, Del EQ less than 0, and Del TA less than 0 are classified as distress. The rest of the firms that partially fulfill the criteria are excluded to keep the healthy and distressed firm samples fairly distinct from each other. Consequently, **8806 and 1753 listed healthy and distress cases** are identified, respectively. Similarly, **2646 and 662 unlisted healthy and distress cases** are identified, respectively.

Methodology

Estimation Procedures

We begin our analysis by estimating the mean values of the financial ratios followed by identifying the key micro-determinants of financial distress using traditional statistical methods and modern machine learning techniques. Analysis has been conducted separately for listed and unlisted cases owing to several reasons. The listed companies are publicly traded relatively large firms whose performance is continuously under scrutiny and therefore related to market sentiment. Such companies involve investment by both institutional and retail investors. In contrast, unlisted firms are closely held small and medium companies that predominantly involve promoter capital and investment by sophisticated private equity investors. They are not exposed to public scrutiny and hence are impacted in a limited way by market sentiment.

First, we construct the matrix of three dependent variables (used as a measure of financial distress) and 30 financial ratios (used as independent variables). The companies with ICR>1 coupled with a positive change in book equity and total assets compared to the previous year are classified as healthy. The companies with ICR<1, and a decline in the equity and asset value as compared to the previous year are classified as distressed. Healthy and distressed firms are labelled 0 and 1, respectively, for each year.

To control high cross-sectional and time series variability in the sample financial ratios, we use the 5^{th} and 95^{th} percentile for removing the outliers. The means for financial ratios are estimated after deleting these outliers. We further standardize these ratios by estimating their standard normal variate.

We next identify the key determinants of financial distress using the feature selection procedure to find the most relevant ratio within each category, i.e., profitability, liquidity, structure, operating efficiency, solvency, and market per-

formance. No feature selection procedure is used for the firm size category as only a single measure (natural log of total assets) is employed, and it is selected automatically. We select the feature with the highest mutual information gain. In this study, each financial ratio is a feature meant to represent a class, i.e., the characteristic of the firm. We identify seven financial ratios for listed and six for unlisted firms (as the category of market-based ratios are unavailable), which will play a role in distress prediction.

Further, we attempt to develop our distress prediction model by pegging our one-year-ahead financial distress dummy to selected financial ratios using the panel logit model as it breaks through linear separation, because the relationship between the probability of financial distress and financial ratios is likely to be nonlinear [41]. We also employ four principal machine learning techniques, namely, RF; ANN; SVM; and GB.

Using the **RF method,** we take T – the number of randomly sampled variables as candidates at each node equal to one thousand and n – the number of trees in the forest is 2, given the achieved optimal model. The **ANN method** has nonlinear and nonparametric adaptive learning properties. For our ANN – MLP (multi-layer perceptron) analysis, we use 50 neurons with ten hidden layers to mimic human decision-making. For **SVM**, our model was optimal with a penalty parameter of 5. We use a radial basis kernel function, an efficient algorithm that introduces additional features in the given space, in a one-versus-all approach. Recent studies have evaluated the **GB** machine for categorization based on specified assessment parameters and found its performance superior to other methods [52; 64]. The hyper-parameters used for our model are: the number of trees – 50, and the maximum depth of a tree – 5. The minimum number of rows, i.e., the fewest allowed observations in a leaf, are set at a default value of 10. The learning rate for our model is set at 0.1, indicating the speed at which our model learns.

The study employs a time-series aware randomised search cross validation, which explores a parameter space from pre-defined parameter distributions. The temporal (panel-data) nature of the data is preserved to avoid any look-ahead bias.

A 5-fold time-series split is employed, training the outer fold, optimising the hyperparameters on the validation part of the inner fold. The optimisation objective is the F1 score of the minority class.

The panel and time series nature of the data has been preserved since the one-year and two-years-ahead predictions are strictly based on the parameters of preceding years of the same company avoiding any data leakage and look-ahead bias. The architectural design reported for the neural network is a starting point and the hyperparameter search tunes that and other model parameters like learning rate, regularization, early stopping and batch size.

We estimate the procedure and recall value for both distressed and healthy cases. Precision shows how much a model's positive predictions are actually correct. It is measured as the ratio of

$$Precision = \frac{True\ Positives}{True\ Positives\ +\ False\ Negatives}. \quad (1)$$

Whereas Recall indicates the actual positive cases correctly identified by the model. It is the ratio of

$$Recall = \frac{True\ Positives}{True\ Positives\ +\ False\ Negatives}. \quad (2)$$

Next, we estimate the expected status (healthy or distressed) for each sample case using the above-mentioned methods. For each method, we compare the expected status with the actual status for the sample cases and derive the prediction rate. A correct case is defined as one in which the expected and actual status match. Incorrect cases are defined as those where discrepancy is observed between the expected and actual status. The prediction rate for a method is estimated by taking the ratio of correct cases to total cases. A higher prediction rate implies better distress prediction. A similar procedure is adopted for predicting two-year-ahead distress. In this case, the two-year-ahead distress dummy is pegged to select financial ratios for the model estimation process.

Experimental Setup

The dataset available for experiments is an unbalanced sample, i.e., **8806** class 1 (healthy firms) and **1753** class 2 (distress firms) cases for the listed firms. Similarly, for unlisted firms, the number of class 1 and class 2 firms is **2646** and **662,** respectively. The data for **4048** and **1868** cases for listed and unlisted samples, respectively, is dropped as these firms don't qualify in either category.

To tackle the issue of unbalanced datasets, class 1 samples are divided into *n* smaller groups so that the number of samples in each smaller group becomes approximately equal to the number of samples in class 2. We obtain *n* datasets by combining each of the n smaller class 1 groups with class 2 samples. Then for each of the *n* datasets, we obtained 5-fold cross-validation with the above-mentioned machine learning algorithms, thus estimating the average classification prediction rate.

Results and Discussions

We provide the mean value of financial ratios (after removing outliers) for both listed and unlisted sample firms in Table 2. These financial ratios have been used as independent variables in our distress prediction models. One can clearly see that listed firms in India exhibit higher profitability on the average compared to unlisted firms with the exception of GPM. Unlisted firms may have better GPM owing to cheaper labour. Labour union activity is either absent or weak in such firms, resulting in better wage negotiation. Unlisted firms also have access to cheaper sources of raw materials with smaller supply chains. They may also exhibit lower direct expenses as the entrepreneur is personally involved or at least supervising the production process. Further, there is a lower degree of variability for the mean profitability measures for healthy and distressed firms in case of listed companies as compared to unlisted companies.

Table 2. Summary statistic (mean value) for financial ratios

Variable	Total Listed Mean	Healthy Listed Mean	Distress Listed Mean	Total Unlisted Mean	Healthy Unlisted Mean	Distress Unlisted Mean
NPM	4.015	8.341	–14.742	1.100	8.900	–24.300
GPM	15.324	17.606	5.065	18.800	22.000	5.800
RONW	8.943	14.506	–9.842	6.700	16.400	–19.900
ROCE	12.603	16.993	–2.255	12.100	19.100	–7.900
ROA	4.255	7.045	–5.725	2.500	7.000	–10.200
QR	1.122	1.208	0.744	1.100	1.200	0.700
CR	1.627	1.736	1.136	1.500	1.700	1.000
NCI	–0.707	0.507	–6.820	–5.300	–2.400	–13.000
CFO/TL	0.069	0.075	0.042	0.100	0.100	0.032
CF/TA	0.002	0.003	–0.003	0.004	0.007	–0.002
CF/OR	0.090	0.091	0.078	0.100	0.100	0.100
WC/TA	0.118	0.155	–0.036	0.100	0.100	-0.100
Eq/TA	0.473	0.508	0.312	0.400	0.400	0.200
CA/TA	0.492	0.512	0.424	0.500	0.500	0.400
CL/TL	0.373	0.353	0.476	0.400	0.400	0.500
FA/TA	0.341	0.333	0.390	0.400	0.300	0.400
SF/NCL	10.665	11.622	6.754	7.100	8.500	4.000
DD	69.178	62.365	90.270	61.900	59.100	71.300
ATR	0.973	1.091	0.619	1.100	1.200	0.800
STR	13.713	14.035	11.842	53.800	53.700	46.300
FL	0.151	0.137	0.202	0.200	0.200	0.300
GR	0.205	0.188	0.268	0.300	0.300	0.400
DR	0.265	0.229	0.422	0.300	0.200	0.500
SR	0.068	0.092	–0.026	0.100	0.100	–0.100
RC	–3.359	–1.193	–16.856	3.300	11.900	–6.200
Debt / Equity	0.743	0.651	1.044	1.000	1.000	0.900
RE/TA	0.402	0.450	0.200	0.200	0.300	–0.100
Total Assets	2233.861	2343.302	1535.481	2012.063	2178.541	1534.059
P/E	18.420	20.568	0.719			
P/B	1.826	2.130	0.953			

We present the level of corporate distress for listed and unlisted firms in India by year. Macroeconomic distress is measured by taking the ratio of distressed companies to total companies each year.

Listed firms exhibit higher liquidity ratios and lower solvency ratios, which makes them fundamentally stronger compared to unlisted firms. They also exhibit relatively lower variability in these financial ratios between healthy and distress firms. It is interesting to note that unlisted firms exhibit better activity ratios compared to listed firms, which implies that operationally they are more efficient. Both types of firms seem to exhibit almost similar structure ratios. The average listed firm seems to be relatively larger in size compared to the average unlisted firm, as per expectations.

We additionally considered size multiples for listed firms as market information is available for them due to public trading. Healthy firms provide a mean P/E ratio of 20.57 compared to 0.72 for distressed firms. Similarly, healthy firms provide a mean P/B ratio of 2.13 vs. 0.95 for distressed firms.

Table 3 provides information about the level of financial distress on a yearly basis for both listed and unlisted sample companies in India. We define a year as the period from April of t-1 to March of t, since the financial closing in India occurs in March. The level of financial distress has been estimated as the percentage of distressed firms to total firms in a given year. It is an indicator of corporate level distress at macroeconomic level [50; 65]. Corporate distress for the listed sample in India stood at 5.62% in 2011 and steadily climbed to 11.58% in 2016, immediately prior to the implementation of Insolvency and Bankruptcy Code. The status was similar for the next three years but increased dramatically from the COVID-19 period in 2020 onwards, showing a jump of 52% compared to the 2016 value. A similar pattern is observed for unlisted companies. The distress rate was 5.59% in 2011, increasing to 10.26% in 2016 and remaining stable around this value for the next three years. It then suffered a meltdown during Covid period reaching a distress rate of 18.68% in 2021, an increase of 82% compared to 2016 value. This indicates a steady increase in corporate distress in India over time, particularly during the COVID-19 period, and a stronger negative impact on the small unlisted companies compared to large listed companies. From the policy makers' perspective, this trend may be of concern and invite greater support to the unlisted sample given their limited capacity to cope with economic meltdowns.

Table 3. Level of corporate distress in Indian listed and unlisted firms

	Number of Listed Companies				
Year	**Healthy**	**Distress**	**Mixed**	**Total**	**Level of Corporate Distress**
2011	875	63	183	1121	0.0562
2012	789	101	239	1129	0.0895
2013	751	91	295	1137	0.0800
2014	722	115	312	1149	0.1001
2015	621	155	373	1149	0.1349
2016	620	133	396	1149	0.1158
2017	672	112	353	1137	0.0986
2018	748	117	266	1131	0.1034
2019	656	130	327	1113	0.1168
2020	494	188	418	1100	0.1709
2021	607	192	292	1091	0.1760
2022	612	189	295	1096	0.1724
2023	639	167	299	1105	0.1511
	8806	**1753**	**4048**	**14 607**	

	Number of Unlisted Companies				
Year	**Healthy**	**Distress**	**Mixed**	**Total**	**Level of Corporate Distress**
2011	215	19	106	340	0.0559
2012	202	25	117	344	0.0727
2013	200	43	105	348	0.1236
2014	207	64	155	426	0.1502
2015	231	56	171	458	0.1223
2016	224	48	196	468	0.1026
2017	233	51	185	469	0.1087
2018	250	60	160	470	0.1277
2019	252	48	172	472	0.1017
2020	210	83	174	467	0.1777
2021	202	85	168	455	0.1868
2022	220	80	159	459	0.1743
	2646	**662**	**1868**	**5176**	

We provide entropy values for each financial ratio used as a measure of given firm characteristic. Financial ratio with the highest entropy value is selected as the best measure of given characteristic.

Table 4. Entropy values based on feature selection procedures for sample financial ratios in case of listed and unlisted firms

Companies	**Listed**		**Unlisted**	
Variables	**1 Yr ahead**	**2Yr ahead**	**1Yr ahead**	**2Yr ahead**
ROA	0.174956	0.136286	0.131302	0.102311
NPM	0.167480	0.126558	0.144521	0.089015
RONW	0.164686	0.130315	0.112464	0.112483
ROCE	0.144807	0.117175	0.110290	0.088199
GPM	0.084506	0.071198	0.060319	0.038205
WC/TA	0.057050	0.035696	0.032311	0.037139
CR	0.051678	0.032672	0.056100	0.035949
NCI	0.048665	0.038003	0.047738	0.025047
QR	0.046754	0.023408	0.043420	0.019853
CFO/TL	0.031477	0.028020	0.024118	0.015016
CF/OR	0.024907	0.021071	0.012655	0.000429
CF/TA	0.013605	0.006265	0.000000	0.000000
Eq/TA	0.057283	0.050482	0.022893	0.043160
SF/NCL	0.055095	0.041293	0.010989	0.027156
CL/TL	0.029133	0.022798	0.020658	0.027988
FA/TA	0.012103	0.011684	0.026625	0.014173

Companies	Listed		Unlisted	
Variables	1 Yr ahead	2Yr ahead	1Yr ahead	2Yr ahead
CA/TA	0.009571	0.011821	0.000000	0.009484
ATR	0.042971	0.022089	0.000265	0.000000
STR	0.030034	0.019934	0.002099	0.000000
DD	0.014123	0.020632	0.010828	0.003709
SR	0.156702	0.123515	0.122026	0.090632
DE	0.071942	0.052404	0.013733	0.013897
RE/TA	0.060222	0.052535	0.062792	0.000792
DR	0.055619	0.042219	0.011867	0.019949
FL	0.023525	0.016491	0.000000	0.007984
RC	0.023238	0.014488	0.005372	0.001240
GR	0.018072	0.017761	0.012518	0.013609
P/E	0.103838	0.067677		
P/B	0.075096	0.060874		

Source: Compiled by the authors

We provide prediction, recall and overall accuracy rate for each financial distress forecasting model for healthy and distressed firms for one- and two-year forecasts. The prediction rate is estimated as the ratio of correctly classified cases to total cases.

In Table 4, we present the information gain value for each financial ratio in a given category for listed and unlisted companies. Information gain measures the reduction in entropy or impurity when a data-set is split on an attribute. It tells us how much information a feature (financial ratio) provides about the class (category). Information gain is used to compare different ratios to determine which one provides the most significant reduction in entropy. This means that it's not an absolute measure but a comparative one. We use it to choose the best attribute at each step in building a decision tree.

Based on feature selection, ROA seems to be the most appropriate measure of profitability for predicting both one-year and two-year-ahead financial distress. Similarly, the optimal measures for structure, operational efficiency, solvency and market-based indicators are FA/TA, Sales Revenue/TA, Solvency Ratio, and Price/Earnings Ratio, respectively. However, a small discrepancy is observed for the liquidity category. While the WC/TA ratio is optimal for one-year-ahead prediction, the (Quick Assets – Current Liabilities)/Daily Operating Expenses ratio is slightly better for the two-year distress prediction. However, to maintain uniformity, we employ the WC/TA ratio for both one-year and two-year-ahead distress prediction. As mentioned in the earlier section, the Total Assets variable is used to represent firm size as it is the only measure in its category.

However, for unlisted firms, we find NPM to be the optimal measure for the one-year-ahead distress prediction. Similarly, CR, FA/TA Ratio, Debtor Days, and Solvency Ratio are found to be the best measures for liquidity, structure, operating efficiency, and solvency, respectively. The selected determinants also seem to work optimally for the two-year-ahead prediction, with the exception of WC/TA, which seems to be better than CR in measuring liquidity by a very small margin. Thus, our factor structure seems to be fairly stable for both one-year and two-year-ahead prediction.

We report the precision and recall values for both healthy and distressed cases in the listed and unlisted samples along with the estimated prediction rate for each model (logit model and select machine learning methods) in Table 5**.** We find that all machine learning methods outperform traditional logistic models for listed as well as unlisted cases for both one- and two-year-ahead predictions. The Random Forest method seems to provide the best one-year as well as two-year-ahead predictions, followed by the SVM method in both listed and unlisted samples. Further, as expected, one-year-ahead prediction rates are slightly higher than two-year-ahead prediction rates in both cases. In fact, RF provides the correct prediction in almost 95% and 91% of rating cases for listed and unlisted firms, respectively, in case of the one-year-ahead forecast.

Table 5. Results of financial distress prediction, recall and accuracy rates for listed and unlisted companies, one- and two-year-ahead (%)

Methods	Listed Firms - 1 Year Ahead: Prediction Rate for Healthy Companies 0	Prediction Rate for Stressed Companies 1	Recall Rate for Healthy Companies 0	Recall Rate for Stressed Companies 1	Overall accuracy	Listed Firms - 2 Year Ahead: Prediction Rate for Healthy Companies 0	Prediction Rate for Stressed Companies 1	Recall Rate for Healthy Companies 0	Recall Rate for Stressed Companies 1	Overall accuracy
Logistic Regression (LR)	78.88	77.43	79.18	77.10	78.18	76.07	75.69	78.15	73.46	75.89
Random Forest (RF)	92.99	96.83	97.21	92.09	94.75	90.72	97.25	97.67	89.22	93.60
Gradient Boost (GB)	90.44	85.52	85.86	90.20	87.95	82.74	88.89	90.79	79.55	85.39
Support Vector Machine (SVM)	89.72	94.31	95.07	88.24	91.78	89.28	83.53	83.72	89.15	86.33
Artificial Neural Network (ANN)	86.99	83.82	84.57	86.34	85.42	82.33	78.86	79.77	81.51	80.61
Methods	**Unlisted Firms - 1 Year Ahead: Prediction Rate for Healthy Companies 0**	**Prediction Rate for Stressed Companies 1**	**Recall Rate for Healthy Companies 0**	**Recall Rate for Stressed Companies 1**	**Overall accuracy**	**Unlisted Firms - 2 Year Ahead: Prediction Rate for Healthy Companies 0**	**Prediction Rate for Stressed Companies 1**	**Recall Rate for Healthy Companies 0**	**Recall Rate for Stressed Companies 1**	**Overall accuracy**
Logistic Regression (LR)	73.00	71.98	74.71	70.17	72.53	71.24	71.40	75.03	67.30	71.31
Random Forest (RF)	88.08	93.47	94.42	86.20	90.47	85.89	91.49	92.80	83.54	88.35
Gradient Boost (GB)	84.12	80.32	81.06	84.47	82.22	82.94	79.78	80.74	82.07	81.38
Support Vector Machine (SVM)	83.26	91.56	93.19	79.76	86.73	79.80	86.34	88.91	75.70	82.56
Artificial Neural Network (ANN)	80.35	76.93	77.95	79.41	78.65	76.18	73.65	75.29	74.58	74.95

Source: Compiled by the authors.

Comparing the feature selection results for listed and unlisted companies, we find common measures of distress prediction in case of structure and solvency characteristics along with firm size, which we measured by using TA for both groups. However, different measures of profitability are found to be optimal for listed and unlisted samples. ROA seems to be the best measure for listed firms, while NPM seems to be a more appropriate measure for unlisted firms. Similarly, in case of liquidity, WC/TA and CR seem to be best measures of listed and unlisted firms, respectively. Different measures of operating efficiency are relevant for the two groups. While ATR is found to be more appropriate for listed firms, Debtor Days is the better measure in the case of unlisted firms. Further, all measures seem to work well for both one-year and two-year-ahead predictions with the exception of the liquidity characteristic. Liquidity measures not only differ for listed and unlisted firms, they also differ for one-year and two-year-ahead predictions in case of both groups.

Comparing the results of listed and unlisted firms, we find a better prediction rate in case of the former group, which may be owing to the availability of market-based information for such companies in the form of price multiples. We recommend using machine learning procedure methods, such as the RF method for both listed and unlisted Indian companies for financial distress prediction. Further, distress prediction models seem to be fairly stable while making both one-year as well as two-year-ahead predictions.

Conclusion

The present study focuses on financial distress modelling and prediction in India. We specifically examine whether similar or different financial ratios predict financial distress in the case of listed and unlisted firms. We find that the same measures of leverage, firm size and structure work in both cases. `However, ROA, WC/TA and Sales/TA seem to be more appropriate measures of probability, liquidity and operating efficiency for listed firms. These firms are relatively large in size compared to unlisted firms, hence the efficacy of financial ratios based on TA is not entirely surprising. In contrast, NPM, CR and debtors collection period seem to be better predictors of financial distress in case of unlisted firms. P/E ratio as a measure of corporate performance provides additional information for listed firms.

We saw the modern machine learning methods, particularly RF, provide better predictions compared to the classical logit model. Further, one-year-ahead predictions are slightly better than two-year-ahead predictions, as per expectations. The study provides important implications for different stakeholders. Policymakers must keep in mind that adverse events like Covid accelerate macro-level distress, which is even more serious for unlisted firm that operate under severe resource constraints. The study suggests the creation of distress prediction models that can be used separately for listed and unlisted firms, which should be of particular interest to bankers since they extend loans to companies and hence would like to keep the financial health of their clients under surveillance. The study also provides insights to companies as to what financial ratios they must keep under watch while maintaining their internal monitoring system. The research also provides information to the academic and research community regarding the key determinants of financial distress and the role of machine learning techniques for forecasting purposes.

We suggest that the subsequent work should include explicit measures of corporate governance as additional determinants of financial distress and should not assume that financial ratios related to profitability, liquidity, leverage and efficiency indirectly reflect the quality of management. Further, it's important to note that the sample companies belong to non-financial sectors, some of which have been more severely disrupted by innovative technologies. We suggest that the sensitivity of corporate performance (measured by sales and/or profits) to the disruptability index should be measured and then used as an additional determinant of financial distress. Such extensions may provide better forecasting of financial distress. It is recommended that a similar exercise be conducted using other emerging market data before drawing any generalizations about distress modelling and prediction. The present study contributes to the financial distress literature, especially as it is related to emerging markets. We recommend that future research on the subject employ a wider range of machine and deep learning techniques, including more recent reinforcement learning models for a sample of emerging markets in order to derive more general conclusions.

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CEO Attributes and Quality of Sustainability Reports of Nigerian Listed Firms

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Abstract

Despite the globally growing emphasis on sustainability reporting among corporations, the quality of information disclosed remains highly variable. While the definition of quality is obscure, managers can use discretion in their report since there is no regulatory policy for the disclosure of non-financial information in Nigeria, which leads to lack of transparency and consistency in sustainability reports. Therefore, this study assesses the relationship between managerial characteristics and the quality of sustainability reports of Nigerian listed firms. The sample includes 76 non-financial firms from several sectors spanning ten (10) years from 2015 to 2024. CEO attributes were proxied with CEO compensation, CEO reputation, CEO gender, CEO turnover, CEO shareholdings and multiple directorships while the study used an index for sustainability reporting quality (SRQ). Since the dependent variable SRQ is a categorical variable, the ordered logistic regression technique was used to run the model for the study. The result showed that managerial compensation, multiple directorships and gender positively influence SRQ, while CEO turnover and reputation have a negative effect on SRQ. However, CEO stock ownership is evidenced to have no significant effect on the quality of sustainability reports. The study findings remain robust when employing an alternative SRQ measure using the ESG disclosure index aligned with the GRI framework. The robustness tests confirm a positive relationship of CEO compensation, ownership and multiple directorships with SRQ while reputation has a negative relationship with SRQ, which is consistent with the ordinal regression result. The research is underpinned by the upper echelons and legitimacy theories, examining how managerial characteristics shape the quality of firms' information disclosure and revealing the fact that average sustainability reporting quality by Nigerian firms challenges the notion that disclosures primarily serve compliance objectives. The study demonstrates the impact of CEO dynamics in advancing corporate sustainability reporting in an emerging market like Nigeria.

Keywords: CEO compensation, CEO reputation, CEO gender, CEO ownership, multiple directorships, CEO turnover, sustainability reporting quality, non-financial firms, Nigeria

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Introduction

Sustainability reporting provides information on the impact of a firm's economic activities and policies on the environment, society as well as governance-related activities. Environmental, Social and Governance (ESG), carbon reporting, corporate social responsibility reporting, sustainability reports have some similarities which are the disclosure of environmental, social, governance, and ethical issues [1]. From empirical research, sustainability reports enhance firms' reputation and shareholder confidence, also improving ESG ratings, among others [2–4]. The evolution of ESG reporting driven by the adoption of standardized frameworks such as Global Reporting Initiative (GRI), European Union's CSRD and International Financial Reporting Standards (IFRS) S1 and S2 underscores the importance of transparency and accountability of firms' sustainability disclosures. When companies disclose their carbon emissions and other sustainability information, such information is analysed by rating agencies that create indicators and metrics to aid in the comparison of such metrics over time and amongst other firms [2]. The effectiveness of these disclosures depends on their usefulness and how reliable such information is to investors in sustainable investment allocation [5].

Although environmental, carbon or sustainability reporting is voluntary in many regions, some countries such as Australia, United Kingdom, France, and New Zealand mandate such reports [6]. These countries have requirements/frameworks that companies must adhere to in reporting this non-financial information. However, in countries with voluntary reporting policies, firms may report short-term positive performance while neglecting or reporting less on negative environmental or carbon performance [6]. ESG adoption is still quite low in emerging markets as global sustainability narratives are in the process of being merged into local institutional frameworks. Unlike emerging markets with less efficient market systems, countries with more robust market and legal institutions communicate information more effectively to reduce information asymmetry and protect investors [7; 8]. This can affect comparability of sustainability reports with global firms. Firms in developing economies such as Africa report their financial and economic activities with less attention to environmental issues [9].

Recently, the African Development Bank (AfDB) and IFRS began collaborating on the ISSB adoption by African firms [10]. Nigeria was the first country in Africa to adopt IFRS S1 and S2 [11]. However, few firms have implemented these standards, as the Financial Reporting Council of Nigeria (FRCN)'s roadmap mandates full adoption of the IFRS sustainability disclosure standards by January 2028 with early adoption permitted from January 2024. Hence, there are variations in the reports of many firms as some entities adopt voluntary standards like the GRI while others scarcely align with any standards.

Managers are saddled with the responsibility of providing relevant information on the company's operations [12]. The Chief Executive Officer is not directly involved in the financial statement preparation directly but may influence the Chief Financial Officer in the manipulation of the reports [13]. It is evidenced by prior studies that managers play a significant role in firms' reporting process [14–19]. Harymawan et al. [18] found evidence that busy CEOs with multiple directorships are associated with financial reporting quality. Also, Adeoye et al. [14] concluded that CEO's compensation influences the quality of financial reports. The study byof Zimon et al. [4] revealed that CEO's power influences the relationship between firms' sustainability disclosure and reputation. Zavertiaeva and Ershova [20] deduced from the upper echelons theory that decisions and firm performance are influenced by CEO's characteristics. Lazareva (2022) [21] in a study of the impact of CEO's personal traits on ESG performance stressed the importance of CEOs in the strategic choices made by the firm, particularly ESG projects. The study carried out on data from Russian firms found that CEO tenure, education, experience, and optimism positively impact ESG performance. Seifzadeh et al. [19] noted that CEO overconfidence and narcissism enhanced the readability of financial statements since these managers are interested in showing off their performance. The research concluded that competent managers present less complex and complicated financial statements based on the theory of managerial ambiguity.

With increasing pressure from stakeholders and non-governmental agencies on environmentally friendly policies, managers may tend to employ greenwashing techniques. Greenwashing is the process of promoting a firm's environmental policies through public relations while not actually making any significant positive environmental impact [2; 3]. These activities are unethical and reveal the difference between managerial disclosure of CSR/ESG activities and real action taken by the firm [22]. This includes tone management and impression management in sustainable reports [22–26]. These strategies affect the quality of sustainability reports and other narrative information being disclosed. The use of infographics for favourable disclosures, structure, visual and reading manipulations, choice of reporting figures and performance are amongst management choices for tone and impression management [22; 25; 26]. Managers may employ these tools to obscure negative environmental or social information and emphasize more positive information; thus, CEO power can be harnessed as an opportunistic tool for discretion in information disclosure [4; 24].

The expansion of the sustainability reporting framework by some African countries has enhanced the need for more research on this subject on the continent. In the context of Nigeria, one of the largest growing markets in Africa, this research situates sustainability practice in a developing economy within the global ESG discourse. Nigeria's voluntary compliance and lax enforcement create allowance for CEOs to influence disclosure decisions as proposed by the upper echelons theory. With this regulatory vacuum, firms may seek legitimacy through disclosures to manage

stakeholders' expectations. Although research on sustainability issues is expanding, the study offers insights into the determinants of sustainability information disclosure with a particular emphasis on the quality of disclosure and the critical role of CEOs. Therefore, this study seeks to assess managerial characteristics which may influence non-financial information quality. This current study examines the reputation, compensation, turnover, multiple directorships, shareholdings and gender of CEOs. While there are existing studies of the impact of managerial characteristics on earnings quality, firm performance, firm value, etc., there is scarcely any research on the influence of managerial attributes on sustainability information disclosure quality. This study fills this gap and expands the current research on managerial behaviour that is associated with reporting quality. In addition, the study expands the recent studies on the quality of corporate information. The next section highlights relevant literature on the study and hypotheses development. The methodology of the study is discussed in the third section while results from data obtained and analysed are presented in the fourth section, with conclusions drawn from these results in the final section.

Review of Literature and Hypotheses Development

Cross-Country Framework

There are mandatory and voluntary reporting requirements in several countries. Only a few countries have developed local regulations for the disclosure of ESG and other non-financial information. The institutional factors of the environment where a business operates affect its reporting system [7; 27; 28]. These institutional factors are social beliefs, and the political and legal system. Institutional dynamics can help to understand the different incentives for sustainability reporting. For example, in China, firms are characterised by majority shareholder control, while developed markets such as US and UK have a more dispersed ownership structure as a result of its market structure and public disclosures mitigating information asymmetry [7; 28].

On the other hand, in economies with weak institutions and less investor protection, there are fewer incentives to communicate effectively to outside shareholders and the stakeholders' group, which may lead to selective disclosure and greenwashing [7]. Sustainability information disclosure will be tailored based on the country-specific governance framework; hence, it can be shareholder-oriented or stakeholder-oriented [7]. Therefore, the differences in the institutional context between countries lead to variations in financial reporting quality by firms [28]. This institutional void influences the relationship between managerial characteristics and reporting quality in emerging markets. Firms in countries with governmental pressure have local reporting regulations that are mandatory for firms, therefore, they curb managerial manipulations in reporting.

In emerging markets where the state has significant control, such as India, Russia, Southeast Asian countries, and Brazil, the firms adopt the stakeholder approach to sustainability practice. In BRICS countries, the institutional-level corporate governance system is a determinant of the disclosure of CSR activities [28–29]. In India, the Business Responsibility and Sustainability Reporting (BRSR) guideline published in 2021 by SEBI required the top 1000 organisations to align and publish ESG information in accordance with the guideline [30]. The author noted an improvement in the quality of sustainability reports of banks using this standard. Similarly, in a study by [31] on the measure of non-financial information disclosure quality by Vietnamese companies, the study assessed the type (qualitative, quantitative and monetary) and volume of information disclosed, as well as future goals in line with the standards of the Vietnam's Ministry of Finance. The research found that Vietnamese firms comply with the standards on non-financial information disclosure. This result is similar to that obtained in the study by Dong et al. [32], which used an assessment disclosure score based on the Transparency Benchmark program by the Netherlands' Ministry of Economics. The author noted that CSR disclosure increases when firms plan to issue more shares or debt the next year.

The European Union comprises a variety of countries with strong and weak institutional frameworks, including legal systems, investor protection, common/code law tradition, and governance oversight mechanisms [33]. The EU recently introduced a new directive referred to as the Corporate Sustainability Reporting Directive (CSRD) 2022/2464, requiring firms to provide more detailed and standartised information on their environmental activities. The CSRD was developed through active collaboration with GRI and ISSB. Countries in the EU are required to adopt this directive in disclosing non-financial information, including ESG information. Studies such as Cicchiello et al. [34] (EU firms); Milena and Lahorka [35] (Croatia); Santamaria et al., 2022 [36] (Italy); Sierra-Garcia et al., [37] (Spain); Kilic and Kuzey [38] (Turkey) employed the EU directives, revealing a high level of adoption of the CSRD guideline by firms in both developed and developing countries in the EU.

Developing countries like Nigeria are characterized by weak quality institutions and fewer capital market developments, which affects the business climate. Low regulatory enforcement, concentrated and mostly family ownership affects the harmonization of the reporting framework. In addition, Nigeria's current voluntary sustainability reporting regime offers managers discretion in reporting ESG information, which may result in tone management and greenwashing in comparison to countries that mandate reporting, hence, the motivation to examine managerial characteristics that affect sustainability reporting quality in Nigerian listed firms.

Sustainability Reporting Quality

Sustainability reports are specifically addressed to stakeholders as a communication tool to reveal effective cor-

porate governance and transparency [39]. Sustainability information is a criterion used by investors in their investment portfolio, and as such, this has enhanced the development of sustainability indices [40–41]. There are variations in the content and information disclosed in sustainability reports as a result of the absence of uniformity in reporting policy, hence, managers use discretion in such reports [2; 42]. Idawati et al. [12] asserted that the presence of a sustainability information in a financial report or a stand-alone report does not guarantee information quality. However, the quality of sustainability reporting reflects the commitment of a firm to environmental, social and economic issues [43]. Determinants of the quality of sustainability reports include corporate governance mechanisms, the use of external assurance provider, standardized reporting framework such as GRI, presence of a sustainability committee [30; 44–46].

In assessing the quality of non-financial information, researchers have constructed and adopted several frameworks. As pointed out by Dong et al. [32], some studies tend to use the issuance or availability of CSR report to proxy for quality of information disclosure, which is grossly inadequate in capturing information quality, hence, firms employ external assurance to verify this information. This independent assurance enhances the credibility of the information and increases stakeholders' reliance on the information disclosed [30; 47]. Also, the use of quantitative information reveals financial commitment and expenditure on environmental-social issues [46; 48–49].

Studies consider the presence of a sustainability committee [45; 47; 49–50] in an attempt to enhance the quality of sustainability information disclosure. The establishment of a sustainability or environmental (social) committee reveals the firm's commitment and strategic position in regard to stakeholders [51]. Al-Shaer and Zaman [52] found that sustainability committees include sustainability targets in CEOs' remuneration package to ensure executives' sustainable behaviours. This committee has an oversight role in ensuring sustainability practices [45; 52].

Furthermore, reporting on activities related to Sustainable Development Goals (SDGs) is expected to improve the quality of sustainability reports. SDGs, also known as the global goals, were adopted by member countries of the United Nations in 2015 as these replaced the Millennium Development Goals (MDGs) [53]. While very few firms presented a sustainability report in their annual report or as stand-alone report before the SDGs, many firms seem to begin to include a sustainability statement in their reports with the advent of the SDGs. Reporting on activities related to the SDGs demonstrates corporations' engagement with sustainability issues, which can enhance information disclosure quality in the sustainability report.

In addition, the use of the Global Reporting Initiative (GRI) standards is expected to enhance the reliance and trust of stakeholders in the information disclosed in the sustainability report. The Global Reporting Initiative (GRI) standard was first launched in the year 2000 as a guideline in the disclosure of non-financial information, including corporate, governance, environmental and social information [43]. The standards are divided into three sections: universal, specific and sectoral standards. These standards have been continuously reviewed and updated to improve information disclosure and reflect global best practices. Studies that employ the GRI standards as a measure of the quality of sustainability reporting include [36; 43; 47; 54].

Theoretical Review

The upper echelons theory introduced by Hambrick and Mason [55] argued that organization outcomes, including strategies and performance, are reflections of the cognitive behaviour of the entity's top manager. The authors emphasized the influence of top management as powerful actors in the firm. They also provided the foundation for research on the relationship between managerial attributes and firm outcomes. The researchers categorized echelon characteristics into two types: psychological and observable. Demographic characteristics of top management teams such as tenure, education, age, compensation, and income are observable attributes while psychological characteristics include cognitive base and values. A fundamental idea of the upper echelons theory is that top executives, such as the CEO and members of the top management team (TMT), play pivotal roles in shaping the firm with their decisions and actions, being guided by their own attitudes, personalities, and values [55]. In line with this theory, studies find evidence that CEOs' personal traits are crucial to the performance of an organization [21; 56; 57].

Therefore, CEO characteristics have a direct impact on organizational outcomes and influence these outcomes indirectly through the actions and dynamics of top management teams (TMTs) [58]. The study by Endiana et al. [59] supports this theory, positing that political affiliations and military connections of top members in a firm improve the quality of sustainability reporting. In addition, Popli et al. [60] reviewed several studies on top managers' psychological and demographic characteristics that affected multinationals' internationalization in respect to the upper echelons theory.

The stakeholder and legitimacy theories are interrelated especially in the context of corporate governance and information disclosure, in other words, environmental/social disclosure may be seen as a governance tool used to ensure accountability and transparency to stakeholders [39]. The stakeholder theory states that a firm is responsible not only to its shareholders but to all stakeholders. Stakeholders are those who affect or can be affected by the actions of the firm. Stakeholders are interconnected through the firms' disclosure of non-financial information such as environmental and social aspects [36]. In respect to the stakeholder theory, sustainability reports are expected to meet the needs of various stakeholder groups and not only shareholders, hence, firms must consider the expectations of other stakeholders [45].

The legitimacy theory is one of the theories that explains the social contract between an organization and society.

This theory suggests that for a company to exist, it must be accepted by society [61]. Financial and non-financial information disclosure helps to legitimize a company's activities as well as enhance stakeholder perception of the firm. Therefore, firms may protect their legitimacy through stakeholder engagement while addressing the gap between stakeholder expectations and sustainability reporting [62]. Furthermore, Crowther and Aras [63] argued that the principal-agent relationship is expanded by the legitimacy theory, and it advances towards stakeholder interests. These theories serve as a framework for the research hypotheses developed in this section. Idawati et al. [12] posits that sustainability reporting is a tool for communicating environmental and social impact of firms' operations, hence, sustainability reporting enables firms to gain legitimacy.

CEO Attributes and Sustainability Reporting Quality

CEO Reputation

An entity with a positive reputation in society will want to preserve its image and goodwill through engaging in environmental and socially acceptable practices [50]. Also, firms disclose sustainability information to project a good social image to stakeholders [64]. Just as documented by studies of corporate reputation, the study by Sridhar [65] proposed that reporting behaviour may be influenced by managers' reputation. Chen and Chen [66] also found an association between managers' ability and the projections in capital expenditures of environmentally sensitive firms. On the other hand, Malmendier and Tate [67] hypothesised that publicly recognized CEOs engage in earnings management, demand more compensation and underperform in subsequent years after the reception of their awards. This aligns with the upper echelons theory, which posits that psychological traits of top managers affect their decisions and choices. To receive more credence and enhance their reputation, more recognized CEOs are likely to disclose more sustainable information than their counterparts. Francis et al. [68] noted that the efficient contract hypothesis indicates that reputable CEOs disclose good earnings quality, thus, reputable managers are knowledgeable and to maintain their reputation, reputed CEOs are expected to take actions resulting to good reporting quality. However, when poor earnings are disclosed by reputable CEOs, it can be linked to the rent-seeking hypothesis. Hence, managers may use their recognition, visibility, and image to report positive information while avoiding the disclosure of information which may affect their reputation. Therefore, the study hypothesizes that:

H1: *CEO reputation positively influences the quality of sustainability reports.*

CEO Compensation

Managerial incentives serve as a mitigating factor for agency conflicts between the shareholders (principals) and managers (agents). Executive compensation may motivate CEOs to act in the best interest of shareholders. Executive compensation includes salary, bonuses, stock and other financial and non-financial benefits. Some components of executive compensation are linked to performance targets which may influence managerial behaviour [14; 69–71]. In a bid to obtain targeted remuneration, managers may make decisions or engage in activities that may affect shareholders' wealth adversely [69]. Al-Shaer and Zaman [52] noted that CEOs' compensation may affect the quality of sustainability information being disclosed, especially when sustainability metrics are included in the compensation agreements. In accordance with the agency theory, managerial compensation serves as a bonding mechanism, thus, when CEOs' compensation is linked with sustainable practices, they will disclose more information since reports serve as a tool of communication with shareholders. The study hypothesizes that:

H2: *There is an association between CEO compensation and the quality of sustainability reports.*

CEO Ownership

CEO shareholding may reduce agency costs and align the interests of the shareholders with those of the managers [71]. CEO share ownership may serve as an incentive for the long-term maximization of shareholders' wealth. With stock ownership, CEOs can influence significant operations and decision-making in the firm, including the selection of directors [73]. When CEOs own shares in their firms, it encourages effectiveness and performance [73–74]. On the other hand, CEO stock ownership serves as a source of power which may result in entrenchment [20]. Moreover, stock ownership may induce managers to make decisions for short-term gains and self-interest [75]. Olorede et al. [69] revealed that CEO shareholdings are significant and positively related to firms' financial reporting quality. Hence, CEO shareholdings could mitigate information asymmetry and increase the disclosure of relevant information. From empirical literature, the study hypothesizes:

H3: *CEO share ownership influences the quality of sustainability reports.*

CEO Turnover

Replacement of managers may arise from age (retirement) or resignation (voluntary or forced), taking up appointments in other firms. A new CEO brings unique and different experiences, perspectives, and values supporting the upper echelons theory. Managerial turnover tends to be a signal to investors on the firm and stock performance [76–77]. However, the dismissal or replacement of a manager is quite difficult when managers have some control or are entrenched in the firm [77]. However, when managers do not achieve shareholders' objectives, they might be subject to replacement or dismissal. The hypothesis of forced managerial turnover by Huson et al. [76] assumes that there is an improvement in firm performance and managerial quality in the event of forced management turnover. [78; 79] document that CEO turnover improves ESG disclosure

and a means of breaking reporting pattern. However, the scapegoat hypothesis holds that managerial performance is based on luck or chance, therefore, managers with poor performance can be fired. In terms of earnings quality, CEO turnover is linked to firms' earnings restatements [15; 80–82]; and turnover of CEOs may lead to tone management, impression as well as greenwashing [83–84]. The study therefore proposes that:

H4: *CEO turnover negatively influences the quality of sustainability reports.*

Multiple Directorships

Managers often tend to hold board positions in other companies. This practice has been found to improve managerial performance, while other studies reveal that this may reduce managerial effectiveness which may result in conflict of interest [18; 85–86]. The resource dependency theory proposes that directors with multiple appointments gain connections, skills, experience and resources that are beneficial to the firm [18; 87]. Moreover, multiple directorships may enhance board effectiveness and monitoring through the connections and networks it creates [88; 89]. However, the study by Al-Haddad et al. [90] supported the busyness hypothesis with their research concluding that multiple directorships have a negative effect on firm value. Other studies document a negative relationship between earnings quality and multiple directorships [85; 91–92]. Busy CEOs may forfeit their responsibilities in their primary appointments, which increases agency costs [18]. The study hypothesizes that:

H5: *Multiple directorships have a negative relationship with sustainability reporting quality.*

CEO Gender

From previous literature, another attribute influencing managerial reporting behaviour is the gender of the CEO. The male-female dynamics was explained using the Upper echelons theory by Perry et al. [93] affirming the benefits of diversity in the managerial team. From the behavioural finance insights, females exhibit unique leadership traits with greater ethical sensitivity, risk perceptions and stakeholder-oriented goals [93–94]. Aligning with the agency theory, female CEOs are often found to enhance transparency, therefore, help to reduce information asymmetry. While Ye et al. [95] found non-significant relationship between gender diversity and reporting quality other studies found that the presence of female directors may enhance higher reporting quality [49; 96–99]. Davis and Garcia-Cestona [94] found that firms are less likely to restate their financial statements when there are more females on the board and the chief financial officer is a female. Garcia-Sanchez et al. [97] noted that more females on board improves the board monitoring role and influences earnings quality. In relations to environmental disclosure, the study by Dyck et al. [98] revealed that firms have more environmental and sustainability performance with more female directors and making provision for majority voting requirements. Al-Shaer and Zaman [96], Olagunju et al. [49], Singhania et al. [99] concluded in their studies that female directors are associated with higher sustainability reporting quality. Furthermore, regulatory policies as well as corporate governance codes have advocated gender diversity in the board setting. This has increased the presence of females on the board, while studies found that gender diversity enhances board effectiveness, therefore, this study tests that:

H6: *The presence of female CEOs positively influences the quality of sustainability reports.*

Methodology

Population and Study Sample

The population of the study included the 102 non-financial firms listed on the Nigerian stock exchange (NGX) as of June 2025. Financial institutions were excluded because of the peculiarities in their financial statements, moreover, other sectors such as industrial, oil & gas, and consumer goods are more environmentally sensitive, therefore, they are expected to provide sustainability reports. The study excludes firms with missing data and recently listed firms, arriving at sample that comprises 76 companies.

Table 1. Study sample across industries

Sector	Total number of firms	Firms with missing or incomplete information
Agriculture	5	0
Conglomerate	6	1
Constructure/ Real Estate	10	5
Consumer goods	20	5
Healthcare	7	2
ICT	8	2
Industrial Goods	12	5
Natural Resources	4	0
Oil & Gas	8	1
Services	20	3
Utilities	2	2
	102	26

Source: Compiled by the author (2025).

Model specification

The study constructs the model as follows:

$$SRQ_{it} = \beta_0 + \beta_1 REP_{it} + \beta_2 COMP_{it} + \beta_3 OWN_{it} + \beta_4 TURN_{it} + \beta_5 MULTP_{it} + \beta_6 GEND_{it} + \beta_7 Controls_{it} + \mu_{it} . \quad (1)$$

Measurement of sustainability Reporting Quality

Several studies use the disclosure index to measure sustainability reporting quality. While this is a good measure, it identifies and confirms information reported in report, it does not necessarily reveal the quality of the reports. This study uses an index whereby scores are assigned based on the availability of the metrics (Table 2). This methodology is suitable for Nigeria given the voluntary reporting regime and absence of uniform sustainability standards/guidelines. Therefore, the observable quality dimensions are deemed appropriate.

Table 2. Index measurement for the quality of sustainability report

Criteria	Source	Score
Existence of sustainability report	Erin et al. [45]; Olagunju et al. [49]; Oyerogba et al. [46]	1, 0 otherwise
Sustainability report includes quantitative data on environmental, economic and social	Oyerogba et al. [46]; Olagunju et al. [49]	1, 0 otherwise
The firm has a sustainability committee	Al-Shaer and Zaman, [52]; Erin et al. [45]; Olagunju et al. [49]; Oyerogba et al. [46]; Sebrina et al. [47]	1, 0 otherwise
Sustainability report includes assurance on the report	Erin et al. [45]; Olagunju et al. [49]; Oyerogba et al. [46]; Sebrina [47]	1, 0 otherwise
Sustainability report includes SDGs activities	Erin et al. [53]; Idawati et al. [12]	1, 0 otherwise
Sustainability report complies with the GRI framework	Hidayah et al. [54]; Michelson [50]; Santamaria et al. [36]; Sebrina et al. [47]	1, 0 otherwise

Source: Compiled by the author (2025).

Variable Measurement

Table 3. Variable Measurement

Acronym	Variable	Type	Measurement
SRQ	Quality of Sustainability Report	**Dependent Variable**	Score 0–6 computed from the score in Table 2
	Managerial Attributes	**Independent Variable**	
REP	Reputation		Measured as dummy variable, 1 if a CEO as awards, recognitions and 0 otherwise
COMP	Compensation		Logarithm of reported CEO emolument
OWN	Share ownership		Proportion of CEO shareholdings to total number of shares outstanding
TURN	Turnover		Measured as dummy, 1 when there is a change in CEO and 0 otherwise
MULP	Multiple directorship		Measured as a dummy, 1 when a CEO is on the board of another firm and 0 otherwise
GEND	Gender		Measured as dummy, 1 when there is a female CEO and 0 otherwise

Acronym	Variable	Type	Measurement
		Control Variables	
LOSS	Loss		Measured as a dummy, 1 when a firm reports a loss during the period, and 0 otherwise
PERF	Firm performance		Measured as a proportion of net income to total assets
SIZE	Firm size		Logarithm of total assets
GOVTOWN	Government Ownership		Proportion of shareholdings held by government agencies and ministries to total number of shares outstanding
MULTINAT	Multinational		Measured as a dummy, 1 when a firm is a multinational corporation and 0 otherwise
FOREOWN	Foreign Ownership		Proportion of shares held by foreign individuals, corporations and institutions to total number of shares outstanding
IND	Industry proxy		Measured as a dummy, 1 for a firm in an environmentally sensitive industry, 0 otherwise

Source: Compiled by the author (2025).

Firm-specific attributes that influence the disclosure and quality of non-financial information include firm size, growth, profitability, leverage, and firm value [43; 45; 46; 49; 54; 66]. Larger firms are exposed to a wide range of stakeholders and have more impact on society in comparison to smaller firms [41]. Also, it is easier for large firms to disclose information on corporate social responsibility compared to smaller companies. When companies report more profit, managers may dwell more on their profitability or performance and focus less on other areas of the annual report such as the sustainability report. In addition, the ownership structure of the firm tends to affect the extent of information disclosure [28; 49; 100-101], therefore, this study controls for foreign ownership, government ownership, and multinational firms. Moreover, the study includes an industry dummy to control for industries that are more prone to environmental sustainability issues such as oil & gas, natural resources, construction, industrial, and manufacturing sectors.

Source of Data Collection

The annual report remains one of the most used sources of obtaining non-financial information, especially sustainability reporting quality. Nevertheless, some firms publish stand-alone sustainability reports, thus, this study obtained information on the SRQ index using both stand-alone reports and sustainability reports in the annual reports.

Method of Data Analysis

The Ordinal/Ordered Logistic Regression technique is suitable for the study because the dependent variable is an ordinal categorical variable, hence the Ordinary Least Square (OLS) is not appropriate for the study. The quality of sustainability reporting is an ordered categorical index ranging from 0–6, representing increasing levels of reporting quality rather than cardinal differences. An ordered logit model therefore appropriately exploits this ordinal structure without imposing linearity or requiring dichotomization, which would result in information loss. There are little differences between the results of logit and probit models. Ordered logit was preferred for the ease of interpretation through odds ratios and marginal effects. We decided to choose logit because it is much easier to interpret and easily readable/understandable. The ordered probit was not adopted because it differs from the ordered logit only in the assumed distribution of the latent error term.

Results and Discussion

Table 4. Summary of SRQ Results

Label	Freq	Percentage (%)	Cumulative
Poor	473	62.24	62.24
Low	86	11.32	73.55
Fair	64	8.42	81.97
Moderate	61	8.03	90.00
Good	47	6.18	96.18
High	24	3.16	99.34
Excellent	5	0.66	100.00
Total	760	100	

Source: Compiled by the author (2025).

For the quality of sustainability report, the study labelled the results for the scores from 0 to 6.

0 = Poor, 1 = Low, 2 = Fair, 3 = Moderate, 4 = Good, 5 = High, 6 = Excellent.

Any item captured will be recorded, and the maximum score is 6, when all criteria are met. The study used both stand-alone sustainability reports by firms and sustainability reports in the annual reports. From Table 4, the relatively large proportion of the firm observations (62.24%) did not disclose sustainability reports in the annual report or as a stand-alone report during the study period. 8.03% of the firm observations had a moderate sustainability reporting quality meeting three of the six criteria while 0.66% of the firms' observations met all the criteria.

Descriptive Statistics

The basic summary statistics of the variables are presented in Table 5. They include the mean, maximum, minimum, and standard deviation of the variables. The average of the log of managerial compensation is 10.41, ranging from 4.79 to 15.18. On managerial stock ownership, the mean of CEO shareholdings is 30.57%, while some CEOs do not own shares in the firm with a minimum of 0. The mean value of multiple directorships and managerial reputation, which are measured with dummy variables are 0.315 and 0.212, respectively, which indicates that about 31.5% of the sampled firms have their CEOs serve on the board of other firms, while 21.1% of CEOs have awards and public recognitions. The average value of gender implies that 31% of the sampled firms are run by female CEOs.

The study controlled for certain firm-specific features such as firm size, loss, and performance. Loss measured as a dummy showed a mean of 0.34. The average firm size is 16.58, ranging from 10.98 to 23.01. Firm performance proxied with return on assets ranges from -1.51 to 0.73. This low performance may be as a result of the COVID-19 pandemic since firms were shut down and operating activities were reduced. Many firms are still recovering from the global shutdown caused by the COVID-19 pandemic. Government ministries and agencies have shares in some companies with an average of 0.52%, while foreign firms and institutions have an average of 17.55% shares in some companies in Nigeria. An average of 19.7% of the sampled firms are multinational corporations.

Table 5. Summary Statistics

Variable	Mean	Max	Min	Std. Dev
COMP	10.40897	15.17879	4.787492	1.751773
OWN	0.305718	0.5507462	0	0.1424393
MULTP	0.314888	1	0	0.4647775
GEND	0.3104517	1	0	0.3104517
TURN	0.1684211	1	0	0.3744862
REP	0.2118421	1	0	0.4088826
PERF	–0.0017348	0.7289066	–1.510478	0.1663879
SIZE	16.57587	23.00782	10.97574	2.02882
LOSS	0.3381579	1	0	0.4733941
GOVTOWN	0.0052477	0.1591	0	0.0240007
MULTINAT	0.1973684	1	0	0.3982748
FOREOWN	0.1755461	0.9742	0	0.2775367
INDU	0.5776316	1	0	0.4942619

Source: Compiled by the author (2025).

Correlation Analysis

A correlation analysis is run to show the association between variables and identify variables with high correlation, which may lead to a problem of multicollinearity. Table 6 presents the correlation matrix between the variables, which showed that there was no strong association between any of the variables. The Variance Inflation Factor (VIF) was also used to identify if there was a presence of multicollinearity. VIF measures the correlation between independent variables, which may lead to collinearity problems in the model. The rule of thumb for the measure of multicollinearity is a VIF score exceeding 5 to 10 with R squared ranging from 0.8 to 0.9 [102], which suggests that a variable in the model might be highly collinear. From Table 7, the highest VIF score is 2.67 (Firm size), indicating the absence of multicollinearity.

Table 6. Correlation matrix

	SRQ	REP	COMP	OWN	TURN	MULTP	GEND	PERF	SIZE	LOSS	GOVTOWN	FOREOWN	MULTN	IND
SRQ	1.0000													
REP	0.1607	1.0000												
COMP	0.6231	0.2873												
OWN	-0.1223	0.2798	-0.0365	1.0000										
TURN	-0.0407	-0.1163	0.0063	-0.1272	1.000									
MULTPDIRE	0.2009	0.5170	0.2477	0.0700	-0.0495	1.0000								
GEND	0.1030	0.1710	-0.0305	0.0385	0.0294	0.0370	1.0000							
PERF	0.0416	0.0047	0.0576	-0.0431	-0.0358	0.0126	0.0867	1.0000						
SIZE	0.5966	0.2336	0.7326	-0.1210	0.0458	0.2323	-0.1618	0.1160	1.000					
LOSS	-0.0829	0.0452	-0.0521	0.0684	-0.0154	0.0303	-0.0178	-0.6764	-0.1017	1.0000				
GOVTOWN	-0.1594	-0.1032	-0.1963	-0.0724	-0.0304	-0.1119	-0.0837	0.0134	-0.1252	-0.0352	1.0000			
FOREIGNOWN	0.3297	0.0749	0.3490	-0.1483	0.0952	0.0258	-0.0183	0.0101	0.3936	-0.0690	-0.1275	1.000		
MULTINAT	0.4085	0.0497	0.3213	-0.1712	0.0876	-0.0018	0.0376	0.0535	0.3413	-0.1204	-0.1258	0.7373	1.0000	
IND	0.3243	0.1220	0.3098	0.0763	0.0911	0.0246	-0.1246	0.1630	0.4206	-0.1555	0.1238	0.2714	0.2694	1.0000

Source: Compiled by the author (2025).

Table 7. Variance Inflation Factor (VIF)

Variable	VIF	1/VIF
SIZE	2.67	0.375008
FOREIGNOWN	2.34	0.428227
COMP	2.33	0.429066
MULTINAT	2.31	0.433389
PERF	1.92	0.521347
LOSS	1.89	0.528996
REP	1.65	0.604475
MULTP	1.43	0.699418
IND	1.41	0.707292
OWN	1.22	0.816986
GEND	1.14	0.875120
GOVTOWN	1.13	0.885589
TURN	1.06	0.967104
MEAN VIF	1.73	

Source: Compiled by the author (2025).

The results of the regression were provided in Table 8. Column 1 provides the baseline regression considering the indices of the sustainability reporting quality (SRQ), while columns 2-7 present the marginal effects of the categorical data (i.e., from Poor to Excellent). The marginal effects show the likelihood of a worse or better quality of sustainability reporting [46]. The Likelihood ratio (LR Chi^2) result (350.35; $p < 0.001$) indicates a strong overall model fit and the independent variables (CEO attributes) explain the levels of sustainability reporting quality. The Pseudo R-square describes the explanatory power and improvement over the baseline, indicating a 25% log-likelihood which is moderate.

The baseline result shows a positive and significant relationship between managerial compensation and sustainability reporting quality (co-eff. 0.7892; $p < 0.0001$), which indicates that an increase in CEOs' compensation would enhance the quality of sustainability disclosure. The result also revealed that an increase in the number of female CEOs will lead to a better disclosure of more information on sustainability issues (coeff. 1.7896; $p < 0.0001$) as the results revealed a significant and positive impact of the presence of female CEOs on sustainability reporting quality. Firms led by female CEOs are much more likely to achieve higher quality sustainability disclosure. Multiple directorships demonstrate a positive and significant effect on sustainability reporting quality (co-eff. 0.4249; $p < 0.1$). CEOs holding positions on other boards are associated with better sustainability reporting.

Table 8. Ordinal Logistic Regression Results

Variables	Baseline regression	Categorical outcome for marginal effects						
		0 = Poor	1 = Low	2 = Fair	3 = Moderate	4 = Good	5 = High	6 = Excellent
REP	–0.7547 (0.2942)**	0.1811 (0.0665)***	–0.0559 (0.0260)**	–0.0715 (0.0264)***	–0.0348 (0.0127)***	–0.0135 (0.0052)***	–0.0045 (0.0019)**	–0.0009 (0.0005)*
COMP	0.7892 (0.1088)***	–0.1966 (0.0269)***	0.0484 (0.0138)***	0.0812 (0.0146)***	0.0429 (0.0087)***	0.0171 (0.0040)***	0.0058 (0.0017)**	0.0012 (0.0006)**
OWN	–2.4775 (1.8125)	0.6172 (0.4516)	–0.1519 (0.1168)	–0.2550 (0.1895)	–0.1348 (0.1009)	–0.0537 (0.0405)	–0.0182 (0.0140)	–0.0036 (0.0032)
TURN	–0.6758 (0.2587)***	0.1633 (0.0596)**	–0.0493 (0.0227)**	–0.0649 (0.0240)***	–0.0318 (0.0117)***	–0.0124 (0.0047)***	–0.0041 (0.0017)**	–0.0008 (0.0005)*
MULTP	0.4249 (0.2410)*	–0.1058 (0.0597)*	0.0230 (0.0127)*	0.0442 (0.0258)*	0.0245 (0.0152)	0.0099 (0.0064)	0.0034 (0.0023)	0.0007 (0.0005)
GEND	1.7896 (0.2942)***	–0.3930 (0.0502)***	–0.0126 (0.0279)***	0.1487 (0.0255)***	0.1462 (0.0374)***	0.0762 (0.0231)**	0.0286 (0.0110)***	0.0059 (0.0033)*
PERF	–1.4145 (1.0512)	0.3524 (0.2619)	–0.0867 (0.0667)	–0.1456 (0.1099)	–0.0770 (0.0592)	–0.0307 (0.0236)	–0.0104 (0.0081)	–0.0021 (0.0018)
SIZE	0.3325 (0.0877)***	–0.0828 (0.0219)***	0.02039 (0.0071)***	0.03423 (0.0101)***	0.0181 (0.0056)***	0.0072 (0.0024)***	0.0024 (0.0009)**	0.0005 (0.0003)*
LOSS	–0.3810 (0.3226)	0.0941 (0.0786)	–0.0253 (0.0235)	–0.0383 (0.0318)	–0.0195 (0.0160)	–0.0077 (0.0063)	–0.0026 (0.0022)	–0.0005 (0.0005)

Variables	Baseline regression	Categorical outcome for marginal effects						
GOVTOWN	–36.3326 (15.0297)**	9.0513 (3.7040)**	–2.2275 (1.2384)*	–3.7396 (1.5414)**	–1.9771 (0.7609)***	–0.7877 (0.3110)**	–0.2662 (0.1143)**	–0.0533 (0.0311)*
FOREOWN	–2.1171 (0.5469)***	0.5274 (0.1358)***	–0.1298 (0.0481***	–0.2179 (0.0612)***	–0.1152 (0,0330)***	–0.0459 (0.0144)**	–0.0155 (0.0057)***	–0.0031 (0.0017)*
MULTN	1.6974 (0.3429)***	–0.3901 (0.0667)***	0.0227 (0.0232)	0.1572 (0.0300)***	0.1254 (0.0335)***	0.0597 (0.0201)**	0.0217 (0.0088)**	0.0044 (0.0026)*
IND	0.6903 (0.2482)**	–0.1688 (0.0590)***	0.0463 (0.0196)**	0.0683 (0.0246)***	0.0349 (0.0132)***	0.0138 (0.0055)**	0.0046 (0.0020)**	0.0009 (0.0006)*
LR Chi² (13)	350.35***							
Pseudo R²	0.2503							

***, ** and * represent significance at p < 0.01, p < 0.05, p < 0.1, respectively. Standard errors are reported in parentheses.
Source: Computed by the author (2025).

CEO turnover and reputation appear to be significant and negatively related to the quality of sustainability reports. The replacement (change) in CEO tends to reduce the quality of sustainability information (coeff. –0.6758 p<0.001), and the quality of sustainability reports is more likely to decline with a more reputable manager (coeff. ––0.7547 $p < 0.05$).

The study rejects the hypothesis of a positive relationship between managerial stockownership and sustainability reporting quality. Managerial stock ownership is not statistically significant (co-eff. –2.4775; $p > 0.1$), thus, it does not affect the quality of sustainability reporting.

From the results of the marginal effects (Column 2–7), for every unit increase in CEO compensation, there is a 19.66% lesser likelihood of poor sustainability information disclosure, a 4.84% greater likelihood of low sustainability reporting quality, and a 8.12% greater likelihood of low sustainability reporting quality. There is a 4.29% greater likelihood that an increase in managerial remuneration results in moderate reporting quality, a 1.71% greater likelihood of good sustainability reporting and a 0.12% greater chance of excellent quality reporting. It is 39.30% less likely that an increase in the number of female CEOs will lead to poor sustainability reporting quality, 14.62% less likely that sustainability reporting quality will be moderate, while an increase in the number of female CEOs will 2.86% more likely be associated with high sustainability reporting quality and 0.59% more likelihood to have an excellent-quality report.

Where a CEO holds appointments on the board of other firms, it is 10.58% less likely that firms have poor sustainability disclosure. There is a 2.30% greater likelihood that an increase in multiple directorships will lead to low sustainability reporting quality, a 4.42% greater likelihood that a sustainability report will be of fair quality, a 2.45% that the quality will be moderate and a 0.34% likelihood of high-quality reporting.

Better CEOs reputation may result in an 18.11% greater likelihood of low sustainability reporting quality, a 5.59% lesser likelihood of poor quality of sustainability reporting, a 7.15% lesser likelihood of a fair quality, a 3.48% lesser likelihood of moderate reporting quality, a 1.35% lesser likelihood of good quality reporting and a 0.09% lesser likelihood of excellent quality of sustainability reporting. Similarly, there is a 16.33% greater likelihood of poor sustainability report quality where there is an increase in CEO turnover, a 4.93% lesser likelihood of producing low-quality reporting, a 6.49% lesser likelihood of fair-quality reporting and a 3.18% lesser likelihood of moderate-quality reporting. An increase in turnover is 0.08% less likely to lead to excellent reporting quality.

Robustness Tests

To ensure that the estimations are not sensitive to modelling assumptions or unobserved heterogeneity by firms, a number of robustness checks are carried out. The researchers conducted a robust test using ESG disclosure by firms following extant studies [36; 43; 47; 54; 59]. The research used ESG disclosure of firms by comparing it with the GRI reporting framework. The GRI reporting framework is an internationally recognized and most widely used framework, which provides guidelines on the disclosure of material sustainability information, and ensures stakeholder inclusiveness [6; 28; 36]. Houque and Khan [6] further confirmed that the United Nations' partnership with the GRI to promote SDGs has made the adoption of the GRI more established. Furthermore, previous Nigerian studies on sustainability reporting disclosure employ the GRI template, therefore, serving as a motivation to employ this standard.

The study post-estimation diagnostic tests include autocorrelation and heteroskedasticity for the robustness result (Table 9). The Woodridge test for autocorrelation showed that the null hypothesis for the absence of autocorrelation

Table 9. Post-Estimation Tests

Woodridge Test for Autocorrelation		
F	484.732	
Prob	0.0000	Presence of Autocorrelation
Breusch-Pagan/ Cook- Weisberg test for Heteroskedasticity		
Chi^2	9.92	
Prob	0.0016	Presence of Heteroskedasticity

Source: Compiled by the author (2025).

is rejected. Also, the p-value for heteroskedasticity indicated the presence of heteroskedasticity. To counter these problems, panel estimations are made using robust and cluster-adjusted standard errors to make sure the process of statistical inference is reliable [103; 104]. To study how the results can be sensitive to other panel specifications, the research estimates linear panel model using pooled OLS and random effects as additional benchmarks (Table 10). The Breusch-Pagan Lagrangian Multiplier (BPLM) test ($chibar^2$ = 1917.80; p.value = 0.000) is a very strong indicator that pooled OLS is not appropriate. In addition, the Sargan-Hansen test (chi^2 = 9.03; p-value = 0.7002) reveals that the random-effects specification is more suitable than the fixed effects. The findings are generally similar in the

Table 10. Robust Regression Results

Variables	Pooled OLS	RE	RE (robust)
REP coeff **Std error**	–0.1620191 (0.0526747)***	–0.1594115 (0.0624154)**	–0.1594115 (0.0632406)**
COMP coeff **Std error**	0.0221292 (0.004326)***	0.039461 (0.0075749)***	0.039461 (0.007675)***
OWN coeff **Std error**	0.0351788 (0.2087192)	0.5907971 (0.2828762)**	0.5907971 (0.286616)**
TURN coeff **Std error**	0.0071507 (0.0496243)	0.0401169 (0.0557428)	0.0401169 (0.0564798)
MULTP coeff **Std error**	–0.0047772 (0.011672)	0.1328798 (0.0526508)**	0.1328798 (0.0533469)**
GEN coeff **Std error**	0.0449459 (0.0628733)	–0.0921436 (0.0700618)	–0.0921436 (0.070988)
PERF coeff **Std error**	0.2067607 (0.1400845)	0.1321066 (0.1929181)	0.1321066 (0.1954686)
FMS coeff **Std error**	0.0894001 (0.0120822)***	0.1051378 (0.0151203)***	0.1051378 (0.0153202)***
LOSS coeff **Std error**	–0.0931488 (0.0498916)*	–0.102151 (0.0622482)	–0.102151 (0.0630712)
GOVT coeff **Std error**	–2.823236 (0.7774069)***	–2.202473 (0.8791784)**	–2.202473 (0.8908017)**
FORE coeff **Std error**	0.0238955 (0.0504247)	1.297648 (0.1199705)***	1.297648 (0.1215566)***
MULTN coeff **Std error**	0.4130519 (0.0666138)**	–0.3653875 (0.0792306)***	–0.3653875 (0.0802781)***
IND coeff **Std error**	0.2475785 (0.0428205)***	0.121372 (0.051368)**	0.121372 (0.0520471)**
C	1.314492 (0.1390905)***	–0.6465991 (0.2208413)**	–0.6465991 (0.2208413)**

Variables	Pooled OLS	RE	RE (robust)
F	38.20***	–	–
R^2	0.4857	0.4854	0.5021
Adjusted R^2	0.4729		
Wald chi^2 (13)		509.87***	482.97**
BPLM			1917.80***
Sargan-Hansen statistics (chi^2)			9.03

Notes: ***, **, and * represent significance at 1%, 5%, and 10% levels, respectively. Also, robust standard errors are in parentheses () while variables are as defined in section 3.
Source: Computed by the author (2025).

form of the signs and significance of the coefficients, indicating the results are not carried out by the unmodelled panel dependence.

Furthermore, to deal with issues of unobserved heterogeneity in ordinal models, the research estimates a random-effects dynamic ordered logistic regression model and compares the outcome with that of the baseline pooled ordered logit model (Table 11). As a dynamic model, we lagged the dependent variable (sustainability reporting quality) in the analysis. The results presented in Table 11 are robust to the main regression results in Table 8. CEO compensation and gender are positive and significantly related to the quality of sustainability reports. CEO turnover revealed a negative influence on sustainability reporting quality, while CEO reputation and interconnectedness were negative but not significant. Although ordered probit model is another estimation model of ordinal outcomes; the difference between the two models lies in the assumed distribution of the error term in the ordered probit models. The ordered logit model is used due to ease of interpretation. Therefore, it is found that the robustness tests indicate the key findings about the relationship between CEO characteristics and the quality of sustainability reports.

Table 11. Robustness Test with Random effects dynamic ordered logistic regression

Variables	Pooled Ordered Logistic Regression	Random effects Dynamic Ordered Logistic Regression
L.SRQ		1.4949 (0.1527)***
REP	–0.7547 (0.2942)**	–0.1038 (0.4124)
COMP	0.7892 (0.1088)***	0.5645 (0.1915)***
OWN	–2.4775 (1.8125)	1.0773 (3.2490)
TURN	–0.6758 (0.2587)***	–0.5081 (0.2927)*
MULTP	0.4249 (0.2410)*	–0.2203 (0.3822)
GEND	1.7896 (0.2942)***	1.0390 (0.4197)**
PERF	–1.4145 (1.0512)	–1.4969 (1.3494)
SIZE	0.3325 (0.0877)***	0.3011 (0.1552)*

LOSS	–0.3810 (0.3226)	–0.2338 (0.3987)
GOVTOWN	–36.3326 (15.0297)**	–10.0775 (12.7945)
FOREOWN	–2.1171 (0.5469)***	–1.4520 (1.1394)
MULTN	1.6974 (0.3429)***	1.6570 (0.8017)**
IND	0.6903 (0.2482)**	1.0807 (0.5824)*
LR Chi² (13)	350.35***	
Pseudo R²	0.2503	
Wald Chi² (14)		209.16***

Notes: ***, **, and * represent significance at 1%, 5%, and 10% levels, respectively. Also, robust standard errors are in parentheses () while variables are as defined in section 3.

Discussion of Findings

This study evaluates the effect of managerial attributes on the quality of sustainability reports. The results of the regression analysis revealed that managerial compensation is statistically significant and positively influences the sustainability reporting quality. This result affirms the propositions of the upper echelons and agency theories, connoting the influence of managerial compensation to reduce information asymmetry. Empirical studies show that managerial compensation influences reporting quality [52; 69; 71]. This is inconsistent with the findings of Adeoye et al. [14]; Iveland and Moe [78]; and Olorede et al. [69] who reported a negative relationship between managerial compensation and financial reporting quality, connoting that managers are motivated to meet earnings forecasts to manipulate financial statements. The positive relationship between CEO compensation and the quality of sustainability reports reflects organisations' practice of performance-based compensation structures. Therefore, in alignment with agency theory, CEO compensation enhances more and better information disclosure.

The study found evidence of a significant and positive relationship of multiple directorships and managerial ownership on one side, and the quality of sustainability reports on the other. Holding multiple appointments enhances the higher disclosure of sustainability information as these CEOs would like to ensure open information disclosure to avoid conflict of interest in fulfilling their responsibilities. Moreover, multiple directorships tend to reveal the professional networks and expertise being derived from sitting on other firms' boards, in alignment with the resource dependency theory thus, refuting the busyness hypothesis. This aligns with the research by Cooper and Uzun [89]; Harywaman et al. [15] which revealed that busy CEOs positively improve financial reporting quality, in alignment with the resource dependency theory. This is not consistent with the results of the studies by Al-Haddad et al. [90]; Ferris et al. [86]; Saleh et al. [92] which found that multiple directorships negatively influence firm performance as they make the managers more busy and less efficient in their primary appointments. Abd Alhadiet al. [85] also documented a negative relationship between multiple directorships and earnings quality.

The study fails to the reject the hypothesis regarding the positive relationship between CEO gender diversity and sustainability reporting quality. The result showed that there is a greater likelihood of high-quality sustainability reporting disclosure as female CEOs are associated with better ethical practices and sensitivity to stakeholders. Females on board are active and enhance the effectiveness of the board, hence, female CEOs are more likely to ensure quality carbon information disclosure [6]. The result is in line with previous studies, which found evidence of the positive influence of female directors on sustainability reporting quality [48-49; 96; 98-99].

The greater the recognition and better the reputation of a CEO, the greater the likelihood of a decrease in disclosure quality. This suggests that CEOs may often believe stakeholders rely on their ability and recognition, and for that reason, not disclose relevant information. Hence, it may appear that to maintain their reputation, CEOs disclose ESG information for compliance purposes, in alignment with the legitimacy theory. In this case, CEOs may selectively disclose positive information, which can serve as impression management/ greenwashing, reducing the quality of the information disclosed. This supports the findings of Malmendier and Tate [67], who documented that award-winning CEOs are mostly busy with other activities external to the company and engage in management of earnings. This is inconsistent with the findings of Michelon [50], who also found that reputation is highly significant and positively related to environmental information dis-

closure. Moreover, the study by Sridhar [67] reveals that managers' reputation influences their information disclosure. Also, Chen and Chen [66] reported that managerial ability enhances the disclosure of environmental financial information.

The regression results reveal a negative relationship between CEO turnover and sustainability reporting quality. This may occur as the new CEO tends to adjust to the position and organization especially when such appointments are not internal, therefore, firms experiencing CEO changes tend to have lower-quality sustainability reporting. This reflects the effects of succession changes in the firm, as the new CEO may take time adjusting to a new environment, hence the need to increase board oversight during CEO turnover. The result aligns with that of extant studies, stating that change of managers negatively affect reporting quality [15; 78; 83]. Niu et al. [84]; Yoo et al. [83] asserted that increased CEO turnover leads to more ESG-washing reports. On the other hand, Bernard et al. [79] found a positive relationship between CEO turnover and sustainability performance, noting that sustainability performance improves when an external CEO is appointed.

The notion that ownership of shares by managers may influence their effectiveness and performance may not be applicable in this case. This supports the study by Al Almosh and Khatib [105]; Idawati et al. [12], indicating that managerial share ownership does not have an impact on the quality of sustainability report, while contradicting the findings of Olorede et al. [49]; Saidu [73], who reported a positive impact of managerial ownership on financial reporting quality.

The results of the control variables reveal that firm size is positive and significantly related to SRQ (coeff. 0.3352. $p < 0.0001$). This connotes that larger firms are more likely to disclose more information and have a higher sustainability reporting quality than smaller firms. This supports previous studies, which claim that bigger firms provide more information than smaller firms [49; 101; 106]. This further attests to the fact that multinational firms tend to produce higher quality sustainability reports (coeff. 1.6974, $p < 0.0001$). Multinational firms are likely to have more quality sustainability reports because of their access and competitiveness in the global market, resources and regulatory scrutiny. Furthermore, industry effects reveal that environmentally sensitive firms disclose more information with a significant and positive impact on the quality of sustainability reporting (coeff. 0.6903; $p < 0.001$).

There is a significant but negative relationship between government ownership and sustainability reporting quality (coeff. –36.3326, $p < 0.05$). Government ownership is less likely to produce better-quality sustainability reports. Foreign ownership has a negative effect on sustainability reporting quality (coeff. –2.1171; $p < 0.0001$). This is contrary to the results of Amidjaya and Widadgo [107]; Sumarta et al. [108], who found evidence of a positive effect of government and foreign ownership on sustainability report.

However, there is a negative non-significant relationship between loss and sustainability reporting quality (co-eff –0.3810. $p > 0.1$). This study also found a similar result in regard to the relationship between firm performance and the quality of sustainability reporting (co-eff. –1.4145. $p > 0.1$). This suggests that less information may be reported when firms report loss or when there is a decline in profit. This contradicts the study by Chen and Chen [66]; Iveland and Moe [78]; Kumar et al. [101], which discovered that managers disclose more information when firm profit increases. Chen and Chen [66] found that firms that reported loss disclose more financial information on environmental issues. However, this aligns with the study by Iyoha and Ohiokha [106]; Olagunju et al. [49], who found that firm performance is negatively associated with firms' environmental disclosure.

Consistent with the Ordinal regression results in Table 8, the robustness test in Table 10 showed that CEO reputation has a negative and significant effect on the quality of sustainability reporting. CEO compensation, share ownership and multiple directorships positively influence sustainability reporting quality. CEO turnover has a negative and significant effect on sustainability reporting quality. The result aligns with the upper echelons theory, which proposes that managerial traits and characteristics affect strategic decisions. However, the relationship between gender and sustainability reporting quality is not significant. The results of the control variables are mostly similar with the SRQ index using the ordinal logistic regression. Government ownership and foreign ownership are negative, while the size of the company, i.e., multinational corporations, positively influences the quality of sustainability report. Furthermore, the findings are consistent with the delayed effects and robust to dynamic specifications as shown in Table 11.

Conclusion

The paper explores CEO attributes (compensation, gender, turnover, ownership, etc.) as determinants of SRQ – a relatively novel intersection in African finance literature. While previous studies (e.g., Olagunju et al. [49]; Erin et al., [46]) examined firm-specific, governance and SRQ, few have integrated such composite CEO-level analysis. This study evaluated the influence of managerial characteristics on the quality of sustainability reports in Nigerian listed firms. The research obtained relevant data from 76 non-financial firms on the Nigerian Exchange Group (NGX). The study utilized an index to measure the quality of sustainability reporting quality which extends the SRQ measure used in previous studies. The results of the study on the index for sustainability reporting quality demonstrated that only few firms had disclosed sustainability reports either in the annual reports or as a stand-alone report. Furthermore, the findings provide evidence of a significant relationship between CEO characteristics and the quality of sustainability information disclosure.

The agency theory posits that CEO compensation may be employed to align with shareholder-managers' interests.

In addition, CEO gender diversity and multiple directorships have significant and positive effects on the quality of corporate sustainability information. Multinational and large firms are more likely to disclose better-quality information from the results of the control variables, while foreign government ownerships are negatively related to sustainability reporting quality. Nigerian firms should design sustainability-linked compensation packages as well as promote more gender diversity in managerial positions to enhance information disclosure quality. In addition, multiple directorships foster reporting quality, and this should be encouraged while regulatory governance structure should be placed for potential busyness concerns and conflict of interest. Conversely, CEO reputation and share ownership often divert attention away from sustainability communication with their image while prioritizing other reporting areas. Previous studies suggest that this behaviour may stem from overconfidence, highlighting the need for strengthened board oversight. In the event of CEO replacement, an appropriate training programme should be implemented to ensure the new CEO is introduced to the culture and practices of the firm.

The study integrates the upper echelons and legitimacy theories. It aligns with the upper echelons theory, confirming the influence of CEOs traits on strategic information disclosure. CEO characteristics influence their values, strategic priorities, and cognitive framework, impacting reporting quality. The result of sustainability reporting quality suggests that firms disclose sustainability information for legitimacy and regulatory adherence to avoid scrutiny over strategic intent; the reporting quality was poor at many firms. This study's results aligns with previous studies in Nigeria and other emerging countries on the influence of CEO characteristics on sustainability performance and reporting quality of firms [14; 52; 56; 69; 70; 78; 84; 96; 100].

The study is significant to shareholders and potential investors as they need relevant and reliable information in the decision-making process, hence, the need for more quality information disclosure, particularly in non-financial information reports. Stakeholders also use non-financial information in evaluating firm operations and governance practices. Moreover, policymakers and regulatory bodies can set minimum requirements for sustainability reports to ensure transparent, comparable and better information. The study's limitation includes the use of CEO's personal attributes while suggesting that psychological traits of CEOs can be explored in future studies. Moreover, the sustainability reporting quality index uses a binary scoring method which focuses on observable quality dimensions considering Nigeria's voluntary reporting environment. In addition, the scope of the study excluded financial firms, while focusing only on non-financial companies.

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The Impact of CEO-Employee Pay Gap on Firm Innovativeness

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Abstract

This study investigates the impact of the CEO-employee pay gap on firm innovativeness, defined as a company's ability to generate economic value from its R&D activities. While prior research has focused on financial performance, the effect of vertical pay dispersion on innovation outcomes remains underexplored, particularly in developed European and Asian markets. Using a sample of public 362 companies from technology-intensive and non-technology-intensive industries over the 2012–2022 periods, we employ the Research Quotient (RQ) as output-elasticity-based measure of innovativeness. Our panel data analysis reveals three main findings. First, the CEO-employee pay gap has a significant negative net effect on firm innovativeness, supporting social comparison and pay equity theories over tournament theory. Second, this relationship is moderated by industry and regional contexts: the negative impact is less pronounced in technology-intensive industries and among firms located in developed Asian countries, where collectivist cultural norms may foster long-term orientation and tolerance for hierarchical differences. Third, we document an indirect moderating effect whereby the pay gap dampens the positive relationship between employee pay growth and firm innovativeness. Our results are robust to fixed-effects specifications and various sensitivity checks. These findings have important implications for corporate governance, compensation design, and investment analysis, suggesting that optimal incentive structures must balance CEO incentives with rank-and-file motivation to foster sustainable innovation.

Keywords: pay gap, firm innovativeness, CEO, employee, research quotient, pay equity theory, tournament theory
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Introduction

Commercialising a firm's innovative research and development (R&D) activities is a vital objective for most companies, as it promotes long-term sustainable growth and competitiveness in a rapidly changing environment [1]. These advantages can be achieved through the development and sale of new products, or by improving cost efficiency through the implementation of cost-reducing technologies. Therefore, the ability to create economic value from innovation-related activities distinguishes successful leaders from other firms. This highlights the relevance and significance of researching firm innovativeness, which can be defined as a company's ability to generate profit from its R&D activities.

The issue of firm innovativeness is of great interest to scholars due to its practical importance for company survival. A significant body of research has been devoted to analysing the organisational factors that affect firm innovativeness and the invention of new products [2; 3]. Planning frameworks, the accuracy of operational execution, customer relationship management and efficient marketing are all confirmed as contributing to company innovation outcomes. The quality of these organisational elements depends heavily on management coordination and support. This is precisely why increasingly more attention is being paid to the influence of top management characteristics, such as age, gender, and experience, on company performance [4]. Prior scientific literature has also examined the relationship between company efficiency and executive compensation, which affects strategic priorities and decision-making processes [5; 6]. However, the impact of top management incentive structures on a firm's innovative capabilities has not been sufficiently researched. Managerial incentives significantly affect important decisions related to company investments, innovation and funding [7]. These decisions lay the groundwork for the company's future performance, prospects, and development path. Therefore, this study focuses on one of the main questions related to this influential factor: the pay gap between the chief executive officer (CEO) and ordinary employees, which represents the firm's incentive structure.

A clear understanding of the relationship between the CEO–employee pay gap (hereafter referred to as the 'pay gap') and firm innovativeness requires detailed academic research to be carried out. The results of this research will be useful in setting up an effective incentive system, which will improve a company's innovativeness and, consequently, its successful development.

The attitudes towards the pay gap between managers, scientists and employees vary depending on the industry and the level of a country's development, among other factors. In this study, we apply knowledge from social equality and tournament theories to increase the company's innovativeness. In accordance with the principles of the wage equality theory, individuals are wont to compare the efforts, experience and talents they invest in their professional activities with the remuneration they receive in return. Consequently, the exacerbation of the wage disparity between CEOs and employees is unlikely to motivate employees to allocate greater effort towards R&D endeavours. In contrast, the principles of the tournament theory have been demonstrated to motivate employees at all levels of an organisation to enhance their performance, thereby inspiring them to generate and execute novel concepts to achieve a superior objective. The persistent incongruities between these two theories highlight the necessity for further research in this domain.

This study aims to determine the presence and strength of the influence of the pay gap between CEOs and non-executive employees on firm innovativeness.

The research focuses on public companies in technology-intensive and non-technology-intensive industries operating in developed European and Asian countries. These two regions are examined because they have unique features, such as cultural and institutional environments, which could affect the relationship between the pay gap and innovative company outcomes.

The vertical pay gap between CEOs and ordinary employees is a poorly understood factor that influences motivation towards the successful commercialisation of innovation activities within an organisation. The scope of the research also includes investigating the industrial specifics of the impact of the pay gap, as well as its indirect effects.

This paper is novel due to the following distinctive features. First, few research papers use the Research Quotient (RQ), a universal and effective measure of firm innovativeness that is superior to conditional indicators such as patents, R&D intensity and expenditure. This study uses RQ (the percentage increase in revenues from a one percent increase in R&D expenditure) to evaluate a company's innovativeness in relation to the pay gap. Second, this research provides an analysis of the industrial specifics of the impact of the pay gap on innovative activities. Third, cultural differences between countries are used as a moderating effect to reflect the relationship between the wage gap and the innovation of companies in developed countries in Europe and Asia. The cultural characteristics of nations, such as individualism, power distance and time orientation, are more closely associated with companies' investment in innovation. According to theory of social equality and the tournament theory, these factors influence workers' attitudes towards such processes. Fourth, this study explores not only the direct effect of the pay gap, but also its indirect effect through its influence on the relationship between employee pay growth and firm innovativeness.

The practical significance of the study lies in the policy implications of its results for company management and investors. First of all, an understanding of the impact of the pay gap on innovative efficiency will help to design an optimal incentive system that improves firm innovativeness. Such a system should balance the innovation motives of personnel and the motivation of top management to promote corporate innovative activities. Furthermore, inclusion of the pay gap as a factor in company analysis, along-

side other drivers of innovativeness, will help investors correctly assess firms' long-term sustainability and growth opportunities.

Using information about the size and dynamics of the pay gap, it will be possible to make more accurate forecasts about fundamental aspects of a company's future development, which largely determine its valuation. Therefore, the results of this study will contribute to the implementation of a reliable investment strategy.

Theoretical framework

Pay gap

The pay gap is a topic that has recently become the subject of active discussion, attracting researchers from many academic fields [8; 9]. The main problems associated with this issue are dispersion and disparity. Some research papers focus on the vertical pay gap, exploring compensation differences between employees at different levels within an organisation [10; 11]. Other studies have examined the horizontal pay gap, describing pay variations among workers at the same level with similar jobs [12]. The present study focuses on the former issue and, more specifically, on the pay gap between rank-and-file employees and CEOs.

The first scientific papers related to this matter appeared in the 1950s, providing the theoretical basis for subsequent research. In 1954, Festinger [13] introduced the social comparison theory, whereby individuals compare themselves to others in order to evaluate their social status. To make such comparisons, individuals choose "referents", or people who seem similar to them. The outcome of this choice and subsequent comparisons is an essential determinant of future behaviour and attitudes towards various aspects of life. Unexplained differences force individuals to act in order to eliminate or at least reduce such anomalies. This tendency has been confirmed by researchers studying different groups, such as CEOs of large, successful firms [14] and students [15].

The next logical step was the pay equity theory proposed by Adams [16]. This theory suggested that workers not only compare themselves to others, but also match the inputs, such as effort, work experience and talents that they put into their work to the outputs they receive in the form of compensation working conditions and social package. This ratio, calculated mentally by taking into account the individual utility of each element, should then be compared to that of other employees. Individuals perceive differences in these ratios as inequalities that must be addressed. This creates pressure, driving individuals to take action to reduce inequity.

Several studies confirm the practical implications of the pay equity theory. According to Fredrickson et al. [17], the growth of the pay gap between CEOs and top management team members negatively affects company performance, resulting from social comparisons among them. Bloom [18] discovered that rising pay variation within a firm worsens results both individually and collectively. Pay dispersion has been found to have a short-term positive effect on company profit [5]. However, this effect becomes negative in the long term. This is due to employees being motivated by immediate benefits rather than acting in the firm's strategic interest.

Another theory that competes with the social comparison theory was developed by Lazear and Rosen [19] and is called the tournament theory. It was further improved and expanded by Rosen [20]. The core idea of the tournament theory is that employee motivation is based on a pay hierarchy. Payment disparity at different levels of the hierarchy motivates employees at both lower and higher levels. Several empirical studies have confirmed the positive association between a vertical pay gap and a company's overall performance, thus verifying the concepts of the tournament theory.

However, an analysis of related research papers revealed several conflicting theories that explain the effect of the pay gap on different dimensions of company performance.

Firm innovativeness

An organisation's innovation capabilities form the basis of its competitiveness and promote sustainable growth in a rapidly changing environment [1]. At the same time, however, R&D investment projects tend to have a long-term outlook and are often characterised by a high degree of uncertainty and a high probability of failure [21]. The practical significance of firm innovativeness, as well as these qualities, have prompted many researchers to study the factors that influence it.

A company's research and development activities are susceptible to external influences such as government policy and the institutional and cultural environment. Gortzen [22] stated that government support significantly promotes the dissemination of technological knowledge by providing funding and tax benefits for joint research projects between private companies. Regulatory policy, the development of advanced institutions and access to human capital and technological solutions have important implications for company innovativeness. Culture is another factor whose impact on corporate performance and innovativeness has been gradually recognised by different scholars. It influences how individuals gain knowledge, prioritise values, and select appropriate behaviours, such as imitation or education. These aspects define an individual's behaviour and shape their personality [23]. The same applies to the decision-making process related to economic activities, where the values, motivations and expectations grounded in culture determine corporate behaviour. Florida [24] argued that the inclusiveness and openness of the people living in a certain region are positively associated with the ability to innovate.

The impact of individualism on firm innovativeness, as it relates to the population of certain regions, was investigated in research conducted by Hofstede [25]. The Hofstede typology consists of six indicators: power distance, individualism, masculinity, avoidance of uncertainty, time orientation and indulgence. These characteristics can only

undergo significant long-term alterations following major global changes. The study of individualism showed that collectivist societies are less creative than individualist ones. This is because individualism promotes individual efforts and freedom, which are beneficial for creative activities, efficient communication and the availability of information, as its main values. Together, these factors contribute to innovative efficiency. Societies with a high degree of individualism, such as those in Western Europe and North America, are characterised by employees who make decisions independently and pursue their own interests rather than those of the firm. This could negatively affect the innovation process due to ambiguous results.

However, collectivism also has advantages in terms of innovation. Collectivist culture, which is prevalent in Asian countries, is characterised by greater interdependence among team members, including the sharing of risks and benefits in long-term cooperation. Collectivism prioritises compliance with rules and tolerance of failure. Due to the long-term nature of R&D projects, which are associated with a high level of uncertainty and a high probability of failure, the characteristics of collectivist societies play an important role in the successful development of innovations.

Firms located in countries with high long-term orientation indicators, such as South Korea and Japan, will have business structures that focus on long-term results. This has a positive influence on the innovative process. The results of this process are only delivered in the long term: thus, the longer the planning horizon, the more likely the company is to engage in this activity. The new product manufacturing process of Japanese companies is the perfect illustration of this theory. Collective cooperation among Japanese employees significantly facilitates the development of innovative manufacturing methods [26].

In the corporate world, the power distance index shows the degree to which management is accessible to employees. In countries with high power distance indices, such as those in Southeast Asia and the Arab world, strategic planning is the responsibility of senior management, with employees simply following orders. This can have a negative impact on the innovative process, affecting the agility of internal dynamics and overall team creativity.

The necessity of innovative product development is determined by industry characteristics, including the level of competition and specifics of dominant strategy. Each year, pharmaceutical, information technology and automobile companies register a significantly higher number of innovative products and patents than companies in other sectors [27]. Therefore, the distribution of innovation is subject to industry specifics. Using data on Korean manufacturing companies, Lee [28] demonstrated that R&D intensity – a measure of a firm's innovativeness – depends on factors such as firm density, the cost structure of R&D projects, the ability to commercialise results and consumer preferences regarding quality and price.

Another study on organisational innovation found that various factors significantly impact a company's new product development at different levels. These factors include an in-depth understanding of customer needs and market conditions, strong strategic planning, and effective coordination between production volumes and cost optimisation [3]. The top management team is responsible for providing oversight and support for all these elements, as well as for determining investment policy and the R&D agenda. Furthermore, the performance of innovative product development depends heavily on corporate culture, collaboration, and communication within the company [29]. Santos and Spann [30] demonstrated the substantial importance of ordinary employees' motivation and willingness to participate in new product development. Therefore, engagement of both rank-and-file employees and top management is essential for a company to commercialise its innovative R&D activities. The behaviour of both groups has a significant impact on the company's overall working climate and culture. The incentive structure at the top and bottom of an organisational hierarchy affects a firm's innovativeness. The configuration of compensation schemes defines individual workers' efforts towards innovative activities [31]. The pay gap between rank-and-file employees and top management reflects the overall shape of a company's incentive structure, making it a highly suitable and reliable indicator. Consequently, it can be assumed that the pay gap is significantly associated with an organisation's ability to benefit from innovative activities.

Although innovative activities are generally considered beneficial, expanding R&D programmes does not necessarily create economic value. The ability to commercialise innovations is vital for any company. This study therefore focuses on this ability by exploring firm innovativeness. The Research Quotient (RQ), also known as Organisational IQ (IQ), which was designed by Knott [32], is a reliable metric for this purpose. RQ represents the output elasticity of R&D spending for each firm and therefore measures its ability to generate revenue from R&D investments.

Relationship between CEO-employee pay gap and firm innovativeness

Prior academic papers on the topic of the pay gap have mainly focused on its influence on a company's financial performance [33]. For example, Yanadori and Cui [12] examined the relationship between a firm's ability to innovate and the level of pay dispersion within the research and development team. They discovered that an increase in the horizontal pay gap among R&D workers reduces the number of patent applications in high-tech companies. However, the authors' results are limited by the business model of high-tech companies and consider only the horizontal pay gap. Wang et al. [11] studied the influence of workers' motivation and voluntary turnover on the relationship between a company's innovative capabilities and the pay gap. Using surveys based on respondents' self-assessment of this relationship, they found that the factors under consideration had a moderating effect.

One of the most relevant studies on this topic was published by Zhao and Wang [34]. They examined how the

pay gap between executives and ordinary employees affects a firm's ability to innovate from the perspective of promoting inventors. The average pay of ordinary employees was used as a proxy for the average pay of R&D department staff. The authors concluded that a wider vertical pay gap could enhance a company's innovativeness, as measured by the number of patents. This improvement could be attributed to the effects of two main mechanisms. First, a larger pay gap creates additional incentives for inventors, who are responsible for innovative outcomes. Since inventors are selected for management positions based on their innovative performance, increased motivation leads to more inventors being promoted. Second, inventors who are promoted to management roles tend to increase investment in R&D projects and involve more R&D staff in management processes due to their professional preferences. Together, these two mechanisms ensure that the pay gap positively influences corporate innovativeness [35].

A review of the extant literature on the pay gap issue suggests that the social comparison theory, the pay equity theory and the tournament theory predict multidirectional effects of the pay gap within an organisation. Therefore, Mingli et al. [27] proposed testing not only the net effect of the pay gap, but also the nonlinearity of the pay gap–firm innovativeness relationship, for which they constructed a quadratic regression model. The authors found that the relationship between an organisation's ability to innovate, as measured by the number of patent applications, and the pay gap follows an inverted-U pattern. The social comparison theory dominates where there is a significant pay gap, while the tournament theory explains the effect where the gap is small. However, subgroup analysis of companies with a small pay gap produced more reliable results. The authors verified whether the above results were robust for companies in technology-intensive industries. The results were consistent.

Apart from its direct influence, the pay gap can have an additional indirect effect on a company's innovative efficiency. According to previously analysed scientific literature, workers are motivated by immediate benefits. A significant part of these benefits is comprised by employee pay. Based on this reasoning, we can conclude that average employee pay growth is associated with an individual's future behaviour and attitude towards the work process. This is particularly relevant for employees and managers in research departments. Numerous studies have confirmed that an increase in the compensation amount has a positive effect on labour productivity, job satisfaction, and overall performance [36]. This is because people tend to compare themselves with others and with their past selves. Furthermore, pay increases may positively affect the motivation of employees to engage in creative and innovative behaviour related to R&D activities. Different research papers claim that the extent of pay inequality among employees affects total satisfaction with working conditions [37]. Therefore, when the rate of CEO compensation growth exceeds the growth rate of ordinary employees' pay (i.e., when the pay gap widens), it creates a sense of inequality that may reduce the positive impact of employee pay growth on firm innovativeness. Thus, the CEO–employee pay gap mitigates the positive impact of employee pay growth on company innovativeness.

Hypotheses development

As posited by Fredrickson et al. [17], the social comparison and pay equity theories, which are predicated on social status comparison within an organisation, suggest that pay inequity has a deleterious effect on the efficiency of a company's innovative activities. Public companies are obliged to disclose a substantial amount of information in order to increase investor confidence. The information provided is increasingly replete with details pertaining to CEO remuneration. These details are disseminated to the general public by the media, due to the high ratings of such publications. Consequently, it is highly probable that rank-and-file employees possess a considerable degree of awareness with regard to the remuneration packages enjoyed by Chief Executive Officers. The existence of a significant vertical pay gap has the potential to engender a perception of inequality among employees, which can adversely impact their motivation and behaviour towards collaboration and innovation. This, in turn, can have detrimental consequences on a company's capacity to commercialise its R&D activities. Concurrently, the principles of the tournament theory posit that a vertical pay gap exerts a positive influence on the innovativeness of firms. This is attributable to the differential remuneration for distinct levels within the organisational hierarchy, which serves as a stimulant for employees across both the lower and higher echelons [19]. It is imperative to undertake a comprehensive investigation into the net effect of the CEO-employee pay gap for companies. This investigation should employ the RQ methodology to ascertain the degree of consistency with the social comparison and pay equity theories, as well as the tournament theory [16; 17; 19]:

H1.1: *According to the theory of social comparison and the pay equity theory, the size of the CEO-employee pay gap negatively affects firm innovativeness as measured by Research Quotient (RQ).*

H1.2: *According to the tournament theory the size of the CEO-employee pay gap positively affects firm innovativeness as measured by Research Quotient (RQ).*

Despite the fact that the default linear model displays a strict dependence on one sign, it merely reflects the net effect. However, the effect of the pay gap within an organisation, as proposed by the social comparison and pay equity theories, is contrary to predictions made by the tournament theory. The multidirectional effects described by these theories have the capacity to engender nonlinearity in the relationships under consideration. Nonlinearity implies that the theories of social comparison and pay equity, or the tournament theory, dominate up to a certain level of pay gap, after which the relationship becomes the opposite [27]. In accordance with this logic, it is recommended that the nonlinearity of the pay gap-firm innovativeness relation-

ship be verified for the sample under consideration by constructing a quadratic regression model.

H2: *The relationship between the CEO-employee pay gap and firm innovativeness is non-linear (quadratic).*

The third hypothesis pertains to a distinctive feature of this study – an investigation of the industrial specifics of the pay gap-firm innovativeness relationship. The necessity of innovative product creation is contingent upon the industry in which the company operates. Enterprises operating within technology-intensive industries demonstrate a markedly elevated annual rate of innovation, as evidenced by the registration of a substantially higher number of innovative products and patents when compared with companies in other sectors. The success of competition and the long-term development of companies in technology-intensive industries is contingent upon the constant implementation of innovations, a feat that cannot be achieved without the involvement of numerous inventors [34]. The authors of the study identified two channels through which the CEO-employee pay gap can influence firm innovativeness: career promotion and pay raises, and promotion of investments in innovations. The primary channel's mechanism is predicated on the significance of fostering innovation as a selection criterion for promoting inventors. This suggests that the widening pay gap engenders further incentives for investors to enhance their innovative output. This phenomenon can be attributed to the second channel's mechanism, which involves an increase in the proportion of inventors within the management team. These individuals tend to allocate a greater amount of resources to R&D activities and to engage more inventors in management roles, often in alignment with their preferences. The overall effect of this dynamic is a positive feedback mechanism between innovative activities, inventor promotion and R&D investments. Consequently, the technology-intensive industry's specifics imply that inventors' promotion incentives related to widening the vertical pay gap become dominant and positively affect firm innovativeness. It is proposed that the relationship between company innovativeness and the CEO-employee pay gap be examined in technology-intensive and non-technology-intensive industries.

H3: *The size of CEO-employee pay gap has a positive effect on firm innovativeness for companies in technology-intensive industries (compared to non-technology-intensive industries).*

As Gortzen [22] concluded in their analysis of the preceding scientific literature, the institutional and cultural environment is found to play an important role in the development of human capital and the ability to access technological innovations. The values, motivations and expectations that are ingrained in a given culture have been shown to have a significant impact on an individual's corporate behaviour [23]. This includes the question of the attitude towards pay inequality represented by the CEO-employee pay gap. As Florida (2004) asserts, qualities such as transparency and inclusivity are conducive to the effective dissemination of information regarding working conditions, employee efforts in the realm of innovative activities, and compensation plans. Furthermore, Hofstede [25] asserts that individualism and collectivism, which are prevalent in societies across diverse regions, exert a substantial influence on labour relations within organisational frameworks. Individualistic societies are oriented towards freedom and creativity and encourage individual efforts, whereas collectivistic ones are characterised by a focus on risk and benefit-sharing in long-term cooperation and higher tolerance for failure. In light of the collectivistic nature of Asian societies and their focus on the long term, it is reasonable to hypothesise that employees of Asian companies are more motivated to contribute to their organisation's long-term development and less discouraged when the pay gap increases. Conversely, employees of European companies that are regarded as individualistic perceive an increasing pay gap as an escalating form of inequality that has a demotivating effect on them. The present study puts forward a hypothesis that reflects the idea of cultural and institutional specifics of European and Asian regions.

H4: *The size of the CEO-employee pay gap has a positive impact on firm innovativeness for companies in developed Asian countries (compared to companies in developed European countries).*

The final hypothesis pertains to the investigation of the indirect impact of the pay gap between a key management team member (CEO) and non-executive employees. As Rambo and Pinto [36] demonstrated, immediate benefits, a substantial portion of which is derived from employee remuneration, play a significant role in the motivation of workers. It is the conclusion of this study that average employee remuneration is associated with future behaviour and attitude to the work process. This, in turn, has a positive impact on the innovativeness of the firm. Conversely, the magnitude of employees' pay inequality has been demonstrated to exert an adverse influence on the aggregate satisfaction with working conditions [37]. Consequently, if the CEO compensation growth rate exceeds the growth rate of ordinary employees' pay, this will engender an increase in the sense of inequality due to a widening pay gap. It is hypothesised that an increase in the CEO-employee pay gap may serve to negate the positive impact of employee pay growth on firm innovativeness.

H5: *Increase in the CEO-employee pay gap reduces positive influence of employee pay growth on firm innovativeness.*

Methodology of research

Step 1. Measuring CEO-employee pay gap

The pay gap is the primary independent variable. As is commonly understood in the scientific literature, the approach to calculating the CEO-employee pay gap is defined as the ratio of the total annual compensation awarded to the CEO to the average compensation of the firm's ordinary employees [33]. It is noteworthy that the mean remuneration of employees is commensurate with that of employees engaged in innovative activities. Furthermore, the average pay is used instead of the median pay, indicating the incen-

tive structure more precisely. This is attributable to the unavailability of disaggregated data. However, the theoretical framework underpinning the study is such that it allows for the use of employees' average compensation for the purpose of this study. As indicated in the preceding literature review, the majority of ratio variations are comparable, exhibiting only minor discrepancies in the composition of elements incorporated into the compensation of CEOs. The elements of this ratio are determined as follows:

- The mean remuneration of the typical rank-and-file employee (denominator). In the absence of data pertaining to individual employees, aggregates such as labour costs (wages, bonuses) will be utilised, with the exclusion of top management compensation. In order to ascertain the mean remuneration of employees, it is necessary to divide the total costs by the number of non-executive personnel in the company.
- The mean aggregate remuneration for a Chief Executive Officer in a specified year, encompassing wages, bonuses, long-term incentive payments and all other forms of compensation (nominator).

In order to exert greater control over the influence of outliers, the logarithm of the pay gap is utilised. In addition, given the construction properties of RQ, which is calculated based on 7-year windows data, the geometric mean of the CEO-employee pay gap is calculated in order to ensure that the main dependent and independent variables are consistent. The subsequent CEO-employee pay gap calculation approach was thus developed:

$$CEO-employee\ gap_t = Geometric\ mean\left(\frac{CEO_{compensation}}{\frac{Labor\ costs - top\ managment\ compensation}{Number\ of\ employees}}\right)_{t:t-6}. \quad (1)$$

Step 2. Assessing firm innovativeness

In the academic literature, a number of scholars have drawn attention to several common approaches to measuring firm innovativeness [27; 38]. These approaches include the size of R&D expenditures, the number of R&D staff, asset intangibility, R&D intensity, and patent-based metrics. However, it should be noted that all of these conventional indicators are subject to certain disadvantages when compared to the Research Quotient, otherwise known as organisational IQ, as developed by Knott [32]. First, it is important to note that R&D expenditures, R&D intensity, and other input metrics are less precise and reliable measures of a company's innovative development. This is because they could potentially reflect low yield or useless R&D costs. It has been demonstrated that patents do not invariably engender economic value. This assertion is substantiated by the example of IT companies, such as Apple and Samsung, which patent numerous inventions that are commercially unviable. Second, patent applications and granted patents, which are the output measures that more accurately reflect the result of the effective use of available resources and cooperation within the company, continue to ignore industry heterogeneity and do not account for the varying profitability of innovations. Finally, existing databases have been found to provide insufficient information on patent applications, especially in developing countries. Formal theoretical arguments were further concretised by Obrimah [39], who stated that both R&D spending and patents are not robust measures of innovativeness and therefore can result in false inferences regarding innovativeness. Conversely, RQ, calculated as the percentage increase in revenues from a one percent increase in R&D expenditures, reflects a firm's ability to generate profit from its R&D investments. Given that the objective of our study is to assess a company's capacity to commercialise its innovative activities, the RQ model is an optimal fit for this purpose.

It is evident that there are several other significant advantages associated with this indicator. First, it is important to note that RQ is unitless in nature, given that it represents the ratio of inputs to outputs. Second, it could be derived for any company engaged in R&D activities and providing financial data. Moreover, RQ is universally applicable due to its uniform interpretation across all companies, irrespective of their industry, thereby rendering it suitable for large-scale research involving firms from diverse sectors. Another crucial feature of RQ is related to its construction aspects, which allow investigating the direction of causal relationships between R&D investments and company performance. In conclusion, it can be demonstrated that the aforementioned arguments collectively substantiate the assertion that RQ functions as a universal and reliable indicator of a firm's innovative capabilities [27].

The present study employs the idea of Knott [40], who based the concept of an innovative efficiency metric on endogenous growth models. The proxy (RQ) for firm innovativeness is defined as the exponent γ_i in the following firm *i*'s production function:

$$Y_{it} = K_{it}^{\alpha} L_{it}^{\beta} R_{i,t-1}^{\gamma} S_{i,t-1}^{\delta}, \quad (2)$$

where Y_{it} is company's output (revenue), K_{it} is capital (net PPE), L_{it} is labor (number of full-time equivalent employees), $R_{i,t-1}$ is lagged R&D expenditures. $S_{i,t-1}$ is lagged spillovers, which are calculated as the aggregate of R&D expenditure discrepancies between the focal firm and its competitors [40]. The calculation encompasses all firms within the industry, as classified by GICS, that have higher R&D expenditures than the focal firm. The Cobb–Douglas production function is used as it provides a single, directly interpretable elasticity of revenue with respect to R&D, which maps cleanly into the RQ measure. In contrast, a translog specification produces local elasticities that vary

with factor levels, making RQ harder to interpret and less comparable across firms and time. Additionally, a translog requires estimating significantly more parameters, and given data limitations, this would substantially reduce precision and may lead to unstable coefficient estimates. As such, the Cobb–Douglas production function is deemed to be a more reliable and transparent choice for estimating firm-level RQ.

The empirical foundation of RQ is the random coefficient (RC) model, which allows for heterogeneity in the elasticity of R&D and other inputs. This heterogeneity is consistent with endogenous-growth frameworks, which explicitly predict heterogeneous returns to innovation across firms. The RC specification allows to recover these heterogeneous slopes, whereas a pooled model would impose an implausible common elasticity. A general functional form model is defined as an estimated RC model, in which the coefficients are considered to be neither fixed nor constant across members of a cross-section or over time. These coefficients may be associated with the error term, as indicated by Knott [40]. In order to estimate the coefficients, it is necessary to utilise the following RC model:

$$\ln Y_{i,t} = (\beta_0 + \beta_{01}) + (\beta_1 + \beta_{1i}) \ln K_{i,t} + (\beta_2 + \beta_{2i}) \ln L_{i,t} + \\ + (\beta_3 + \beta_{3i}) \ln R_{i,t} + (\beta_4 + \beta_{4i}) \ln S_{i,t-1} + \varepsilon_{i,t}. \quad (3)$$

where the research quotient (RQ) indicator presented by the sum $(\beta_{3+} \beta_{3i})$ for each firm. The random-coefficients linear-regression model for panel data utilised in this research necessitates a minimum of seven years of complete data for estimation. As each estimation yields a single value, the dependent variable is constructed by utilising rolling seven-year windows for each firm-year, commencing from 2010 to 2016. Consequently, the estimation window is updated by incorporating the most recent year and omitting the earliest one, thereby facilitating the calculation of RQ for the 2016–2020 period [41]. The present study diverges from preceding research in that it employs manually calculated indicators, a departure from the automated methods utilised in previous studies.

Step 3. Defining control variables

The size of the firm has been demonstrated to affect the probability of investing in innovative activities and the ability to benefit from these investments [32]. It is evident that the magnitude of the firm is regulated through the utilisation of the logarithm of the entity's market capitalisation.

As demonstrated by Yanadori and Cui [12], there is a positive correlation between the commercialisation of innovative activities and the success of firms, as measured by profitability. Furthermore, this correlation has a beneficial impact on the innovativeness of the firm. Consequently, it is imperative for a company's performance to be governed by the utilisation of a return on assets (ROA) metric.

The firm's future prospects and growth opportunities could also significantly affect its innovative capabilities, so they are controlled by using the price-to-book value ratio [17]. The indebtedness level of a company, measured as the ratio of long-term and current debt sum to total assets, was utilised as a control variable for management risk appetite. This risk appetite has been demonstrated to influence the decision to invest in long-term, risky R&D projects [42].

The objective of the present study is to examine the impact of employee compensation growth over time. To this end, the log-transformed growth in CEO compensation is maintained constant. In order to ensure that all variables within the model are consistent, the geometric mean of the control variables for the 7-year windowed data must be calculated. Table 1 presents the control variables and their calculation methodology.

Table 1. Overview of the control variables

Control variable	Calculation methodology
Firm size (logarithm)	$\ln(market\ capitalization) = (year-end\ stock\ price \times common\ shares\ outstanding)$
Firm performance	$ROA(Return\ on\ assets) = \frac{Net\ income}{Total\ assets}$
Growth opportunities	$Price-to-book\ value\ ratio = \frac{Market\ vaue\ of\ equity}{Book\ value\ of\ equity}$
Management's risk tolerance	$Leverage\ ratio = \frac{Total\ long-term\ debt + Current\ liabilities}{Total\ assets}$ $Leverage\ ratio = \frac{Total\ long-term\ debt + Current\ liabilities}{Total\ assets}$
CEO pay growth	***CEO pay growth = Percentage change in CEO compensation (log transformed) from year t-1 to year t***

Source: Authors' investigation.

Step 4.1

The empirical model is proposed for testing the first hypothesis regarding the net effect of the CEO-employee pay gap on firm innovativeness (H1.1, H1.2):

$$RQ_{i,t} = \beta_0 + \beta_1 \ln(PayGap)_{i,t-6} + \beta_2 \ln(MarketCap)_{i,t-6} + \beta_3 ROA_{i,t-6} + \\ + \beta_4 Price-to-book\ value\ ratio_{i,t-6} + \beta_5 Leverage_{i,t-6} + \beta_6 \ln(CEOPayGrowth)_{i,t-6} + u_{i,t}, \quad (4)$$

where $\beta_{0\ \text{is}}$ constant, $\ln(PayGap)_{i,t-6}$ is the geometric mean of the logarithm of the CEO-employee pay gap, $\mathrm{n}(MarketCap)_{i,t-6}$ is the geometric mean of the logarithm of the company's market capitalization, $ROA_{i,t-6}$ is the geometric mean of a firm's return on assets, $Price-to-book\ value\ ratio_{i,t-6}$ is the geometric mean of a company's price-to-book value ratio, $Leverage_{i,t-6}$ is the geometric mean of a firm's leverage, $\ln(CEOPayGrowth)_{i,t-6}$ is the geometric mean of a company CEO's compensation growth (in logarithm).

Step 4.2

In order to undertake a rigorous investigation into the nonlinear relationship between pay gap and firm innovativeness, it is necessary to construct a quadratic regression model (H2):

$$RQ_{i,t} = \beta_0 + \beta_1 \ln(PayGap)_{i,t-6} + \beta_2 \ln(PayGap)^2_{i,t-6} + \beta_3 \ln(MarketCap)_{i,t-6} + \beta_4 ROA_{i,t-6} + \\ + \beta_5 Price-to-book\ value\ ratio_{i,t-6} + \beta_6 Leverage_{i,t-6} + \beta_7 \ln(CEOPayGrowth)_{i,t-6} + u_{i,t}, \quad (5)$$

where $\ln(PayGap)^2_{i,t-6}$ is squared logarithm of CEO-employee pay gap geometric mean and other variables are the same as for the first hypothesis.

Step 4.3

The relationship between the CEO-employee pay gap and firm innovativeness is hypothesised to be significantly affected by industrial differences. This has important incentive policy implications for companies that operate in various industries. The significance of these differences is examined by incorporating corresponding dummy variables and their intercepts with the pay gap in the model. The classification of industries is typically divided into two categories: technology-intensive and non-technology intensive. The classification of economic activities employed in this division is derived from the OECD taxonomy of economic activities [43]. In order to evaluate the effect of the pay gap on innovative capabilities for companies from technology-intensive and non-technology-intensive industries, the following model is specified (H3):

$$RQ_{i,t} = \beta_0 + \beta_1 \ln(PayGap)_{i,t-6} + \beta_2 Industry_i + \beta_3 Industry \times \ln(PayGap)_{i,t-6} + \beta_4 \ln(MarketCap)_{i,t-6} + \\ + \beta_5 ROA_{i,t-6} + \beta_6 Price-to-book\ value\ ratio_{i,t-6} + \beta_7 Leverage_{i,t-6} + \beta_8 \ln(CEOPayGrowth)_{i,t-6} + u_{i,t}, \quad (6)$$

where $Industry_i$ is the industry dummy that equals 1 for firms in tech-intensive industries and 0 for others; $Industry \times \ln(PayGap)_{i,t-6}$ is the interaction term between the industry dummy and the pay gap variable, and other variables are the same as for the first hypothesis.

In order to evaluate the impact of the pay gap on the innovative capabilities of companies operating in developed European and Asian countries, the following model (H4) is specified:

$$RQ_{i,t} = \beta_0 + \beta_1 \ln(PayGap)_{i,t} + \beta_2 Region_i + \beta_3 Region \times \ln(PayGap)_{i,t} + \beta_4 \ln(MarketCap)_{i,t-1} + \\ + \beta_5 ROA_{i,t-1} + \beta_6 Price-to-book\ value\ ratio_{i,t-1} + \beta_7 Leverage_{i,t-1} + \beta_8 \ln(CEOPayGrowth)_{i,t-1} + u_{i,t}, \quad (7)$$

where $Region_i$ is the region dummy for companies that operate in developed countries of Asia and Europe, $Region \times \ln(PayGap)_{i,t}$ is the interaction term between region dummy and the pay gap variable, and other variables are the same as for the first hypothesis.

Step 4.4

In order to calculate the indirect effect of the pay gap via employee pay growth, it is first necessary to calculate employee pay growth. This indicator is intended to represent a percentage increase in the average employee remuneration for a given year. In order to confirm or refute this hypothesis, it is necessary to incorporate an additional continuous variable and its interaction term with the primary independent variable of interest into the regression model. (H5):

$$RQ_{i,t} = \beta_0 + \beta_1 \ln(PayGap)_{i,t-6} + \beta_2 EmployeePayGrowth_{i,t-6} + \beta_3 EmployeePayGrowth_{i,t-6} \times \ln(PayGap)_{i,t-6} + \\ + \beta_4 \ln(MarketCap)_{i,t-6} + \beta_5 ROA_{i,t-6} + \beta_6 \mathrm{Pr}ice-to-book\ value\ ratio_{i,t-6} + \beta_7 Leverage_{i,t-6} + \beta_8 \ln(CEOPayGrowth)_{i,t-6} + u_{i,t}, \quad (8)$$

where $EmployeePayGrowth_{i,t-6}$ is the growth of employee pay from year t-1 to t (geometric mean), $EmployeePayGrowth_{i,t-6} \times \ln(PayGap)_{i,t-6}$ is the interaction term between the employee pay growth and pay gap variables. Alternative lag structures consistent with R&D and innovation dynamics were explored during the development of the empirical specification. The results across these alternative lag lengths were broadly consistent, and the lag structure reported in the manuscript was selected because it delivered the most stable and economically meaningful estimates. This reinforces the robustness of the reported findings.

Table 2. Distribution of companies by industry and region (%)

	Industrial distribution
Technology-intensive	11.57
Non- technology-intensive	88.43
	Regional distribution
Developed Asian countries	17.8
Developed European countries	82.2

Source: Authors' calculations.

Research sample and data sources

The primary focus of this research is on European and Asian developed markets, as these societies offer a rich and diverse context for the analysis of cultural differences and institutional development. The entire corpus of company data was obtained from the Bloomberg database for the period from 2012 to 2022 inclusive. The construction of the RQ variable, incorporating one-year lagged R&D spending and R&D spillovers, necessitates a minimum of seven years of complete data to estimate coefficients using the RC model. The sample under consideration contains 1,188 firm-year observations for 362 companies. These companies operate in 21 countries, including 16 European and 5 Asian countries. The data also includes information about industries in which companies operate according to GICS.

As illustrated in Table 2, the firm's distribution is demonstrated by industry (technology-intensive and non-technology-intensive) and region (developed Asian and European countries). A mere 11.57% of the firms operate in technology-intensive industries. The majority of the companies in our sample are those with business operations in developed European countries – 82.20%.

Table 3. CEO compensation and pay gap descriptive analysis

	Min	1st quant.	Median	Mean	3rd quant.	Max
CEO compensation:	0.70	1.09	1.61	2.10	2.48	29.25
Technology-intensive industries	0.07	0.95	1.18	1.96	1.63	28.15
Non-technology-intensive industries	0.10	1.15	1.74	2.13	2.65	29.25
Developed Asian countries	0.07	0.96	1.23	1.82	1.80	28.15
Developed European countries	0.10	1.14	1.18	2.20	2.72	29.25
CEO-employee pay gap:	1.82	17.49	27.88	42.82	45.84	1 013.04
Technology-intensive industries	3.21	23.11	41.90	82.66	85.39	1 013.04
Non-technology-intensive industries	1.82	16.56	26.30	35.09	41.73	418.28
Developed Asian countries	3.21	23.67	41.03	72.82	83.80	1 013.04
Developed European countries	1.82	15.93	24.66	32.96	39.24	418.28

Source: Authors' calculations.

The present study considers CEO compensation and the CEO-employee pay gap through the lens of descriptive statistics, with a focus on industrial and regional detail, as illustrated in Table 3. It is evident from the provided statistics that Chief Executive Officer remuneration is, on average, higher in companies that operate in non-technology-intensive industries. However, a notable disparity emerges in the mean CEO-employee pay gap, with non-technology-intensive industries exhibiting a substantially lower mean gap compared to their technology-intensive counterparts. A study of regional distribution reveals that Chief Executive Officers of companies operating in developed Asian countries receive lower levels of compensation. However, the inequality between the top and bottom levels of an organisation's hierarchy is significantly lower for companies from developed European countries, which are considered more individualistic. Furthermore, it has been determined that over 75% of all organisations have CEO compensation that is less than 50 times higher than average employee pay.

Table 4 provides descriptive statistics of variables included in the regression model. On average, a company's R&D investments contribute to around 31% of its revenue increase.

Table 4. Descriptive statistics

	Min	1st quant.	Median	Mean	3rd quant.	Max
RQ	–2.75	0.04	0.27	0.31	0.57	3.91
CEO-employee pay gap	1.82	17.49	27.88	42.82	45.84	1013.04
Market cap	41.16	2050.18	5417.42	12 859.18	13 135.36	201 564.8
ROA, %	0.39	3.61	5.33	6.13	7.43	28.65
Price-to-book	0.54	1.60	2.46	3.23	3.51	197.32
Leverage	0	0.07	0.15	0.16	0.22	0.59
CEO pay growth, %	-87.03	–3.24	3.08	10.67	12.26	444.09
Industry	0	0	0	0.16	0	1
Employees pay growth, %	–20.90	–1.86	–0.12	3.11	1.72	822.87

Source: Authors' calculations.

Empirical results

Given that the sample under consideration consists of repeated firm-year observations, panel data models are employed. Fixed effect (FE) and random effect (RE) models are the most commonly used panel data models. The FE model is compared with the RE model using the Hausman test. The findings of this study indicate that the FE model is to be preferred over the RE model in instances where specifications encompass year dummies. In instances where the random effects model is deemed to be the superior option, as determined by the Hausman test, the Breusch-Pagan Lagrange multiplier (LM) test was also conducted. This test serves to compare the RE model with the ordinary least squares (OLS) model. The outcomes of the LM test demonstrate that the RE model is suitable. Hence, the empirical analysis follows a two-stage structure. First, firm-level RQ values are obtained using a random-coefficients production-function model with firm fixed effects. Second, these RQ estimates are used as dependent variables in fixed-effects or random-effects panel regressions. Such mixed specification allows for capturing firm-specific R&D elasticities prior to the second-stage regressions and incorporates both fixed effects and random coefficients where theoretically appropriate.

The presence of heteroskedasticity is checked by applying a modified Wald test for groupwise heteroskedasticity to the FE model. The findings suggest the presence of heteroskedasticity in the model, as evidenced by the significant value of the Chi-squared statistic (1.1e + 07) and the low p-value (0.000) for H1. The issue of endogeneity was addressed by performing the Durbin-Wu-Hausman test. The findings of this investigation indicate that the predicted residuals of the potentially endogenous variable of main interest are not significant (p-value: 0.555). This outcome suggests the absence of an endogeneity problem.

In order to ascertain whether the results obtained are influenced by multicollinearity, the correlation matrix is estimated, as presented in Table 5. This matrix demonstrates the correlation between the variables that have been utilised. As demonstrated in the matrix, there is an absence of substantial correlation between the variables in the dataset. The variance inflation factor (VIF) is a measure of the degree to which the variances of a set of variables may be biased by common factors. It is evident from the VIFs (less than 2) and correlation matrix values obtained that there is no significant multicollinearity, and the sustainability of the results is substantiated.

Table 5. Correlation matrix

	RQ	CEO-employee pay gap	Market cap	ROA	Price-to-book	Leverage	CEO pay growth	Industry	Employee pay growth
RQ	1								
CEO-employee pay gap	0.0231	1							
Market cap	0.1062	0.1381	1						
ROA	0.0903	–0.0267	0.0457	1					
Price-to-book	0.0125	–0.0309	0.0390	0.2925	1				
Leverage	–0.1115	–0.0771	0.1522	–0.1985	0.1816	1			
CEO pay growth	–0.0389	0.1169	–0.0652	–0.0285	–0.0100	–0.1568	1		
Industry	0.0147	0.3355	–0.1022	–0.0606	–0.0702	–0.2024	–0.0141	1	
Employee pay growth	0.0077	0.0722	–0.0344	–0.0143	–0.0070	0.0053	0.0112	0.1086	1

Source: Authors' calculations.

Table 6. Analysis of the net and nonlinear effect of the pay gap on firm innovativeness

Variable	Model 4 – H1.1 & H1.2 (FE)	Model 5 – H2 (FE)
CEO-employee pay gap	–0.1481* (0.0823)	–0.1846 (0.3409)
CEO-employee pay gap (squared)		0.0045 (0.0376)
Market cap	0.0724 (0.1741)	0.0702 (0.1792)
ROA	0.5757** (0.23667)	0.5752** (0.2357)
Price-to-book	–0.0174 (0.0197)	–0.0174 (0.0197)
Leverage	0.2587** (0.1023)	0.2585** (0.1026)
CEO pay growth	–0.0467 (0.0749)	–0.0465 (0.0747)
Constant	0.7142** (0.3407)	0.7155** (0.3419)
Year dummies	Yes**	Yes**
R^2	0.005	0.005
Number of firm-year observations	1188	1188

Notes: Robust standard errors clustered by the firms are provided in parentheses. : Respective standard errors are presented in the brackets. Table 6 reports the FE specifications corresponding to Equations (4) and (5) .
*** p < 0.01, ** p < 0.05, * p < 0.1.
Source: Authors' calculations.

In accordance with the findings of the Model 4 regression, the results are displayed in Table 6. The β-coefficient for the CEO-employee gap indicates that a 1% increase in the pay gap is concomitant with a 0.1481% decrease in RQ. This finding suggests that the disparity in remuneration between CEOs and employees exerts a substantial deleterious effect on the innovation capacity of firms (*hypothesis H1.1 is accepted and hypothesis H1.2 is rejected*). These outcomes serve to substantiate the predictions of the social comparison and pay equity theories [13; 16; 19] and refute the implications of the tournament theory [19]. The theory postulating the existence of a negative pay gap as a consequence of social status and the ratio of inputs (efforts) to output (compensation) comparison between individuals within the organisation is linked to the social comparison and pay equity theories. The outcome of this comparison plays an essential role in determining employee behaviour, labour efforts and attitude to innovative activities. It is evident that both ordinary employees and well-educated inventors are most likely to be aware of CEO remuneration packages. This is due to an increase in the requirements for companies to disclose information, as well as the media paying greater attention to such publications. The increase in the vertical pay gap engenders a sense of inequality that has the potential to demotivate employees and adversely affect behaviour towards collaboration and innovation. This, in turn, can have a detrimental effect on a company's ability to commercialise its R&D activities.

In addition to the net negative effect, the impact of the CEO-employee pay gap may exhibit a non-linear (squared) nature, resulting in a multidirectional influence on a firm's innovative capabilities, contingent on the size of the pay gap. The results of the study are presented in Table 6 (Model 5). The findings suggest that there is no statistically significant nonlinear (squared) effect of the pay gap on firm innovativeness, thereby *rejecting Hypothesis 2*. The majority of companies in the sample exhibited a pay gap of less than 50 times the difference, which may not be sufficient to provide substantial positive incentives for employees to engage in innovative activities. In consideration of the findings, it can be deduced that the ramifications of the tournament theory [19] with regard to innovation commercialisation remain unvalidated for the sample under scrutiny.

Further significant results pertain to the testing of Hypothesis 3, which explores the industrial disparities in the relationship between the pay gap and firm innovativeness. The distribution of innovation is contingent upon the particularities of each industry; companies operating within sectors such as pharmaceuticals, information technology and automobiles, for instance, are responsible for a substantially higher number of inventions on an annual basis when compared with companies from other industries [28]. The findings of this study demonstrate that the interaction term between the CEO-employee pay gap and industry dummy is positive. This suggests that, in comparison with non-technology industries, the CEO-employee pay gap is more beneficial for companies operating in technology-intensive industries (see Table 7). The pay gap expansion by 1% has been shown to increase the ability to commercialise innovations measured by RQ for companies that operate in technology-intensive industries by 0.0451% compared to non-technology intensive industries (*Hypothesis 3 is accepted*). The results obtained are consistent with the findings of Zhao and Wang [34], who based their research on the concepts of the tournament theory [19]. The rationale underpinning this phenomenon pertains to the substantial involvement of a considerable number of inventors in a perpetual process of innovation implementation. This is a prerequisite for effective competition and the long-term development of companies in technology-intensive industries. The widening pay gap engenders further incentives for investors to enhance their innovative output. This phenomenon results in an augmentation of the proportion of inventors within the management team, who, in turn, allocate greater resources to R&D activities and engage a higher number of inventors in management roles, driven by their personal preferences. The positive feedback mechanism between innovative activities, inventory promotion and R&D investments is well-documented. Consequently, the technology-intensive industry's specifics imply that inventors' promotion incentives related to increasing the CEO-employee pay gap become dominant and positively affect firm innovativeness measured by RQ.

The seventh model (see Table 7) investigates the impact of regional factors on the correlation between the pay gap and firm innovativeness between European and Asian countries. The findings of the study indicate that there is a 1% increase in the CEO-employee pay gap in companies that operate in developed Asian countries, which results in a 0.0200% rise in the firm's RQ (*Hypothesis 4 is accepted*). These results are consistent with Hofstede's theory, which predicts that Asian societies that are considered to be collectivistic have a focus on risk and benefit-sharing in long-term cooperation, and a higher failure tolerance [25]. The long-term nature of R&D projects, which is associated with a high level of uncertainty and the possibility of failure, has been shown to enhance firms' abilities to commercialise their innovations. This phenomenon can be recognized as a characteristic of a collectivistic society and attributed to the tendency of Asian employees to prioritise the long-term strategic interests of the firm over short-term benefits [44].

When assessed in relation to regional and industry-specific factors, control variables such as firm size, profitability and financial leverage were found to be significant. This finding is consistent with the conclusions of previous studies [32,12, 42]. The impetus to commercialise innovation activities is observed to increase among larger, successful companies that adopt a risk-averse approach to implementing long-term innovation projects.

The present study considers the hypothesis (*H5*) regarding the indirect effect of the CEO-employee pay gap via employee pay growth. As illustrated in Model 8 (see Table 7), the findings demonstrate the substantial and negative impact of the pay gap, thereby moderating the positive

relationship between employee pay growth and firm innovativeness, as measured by RQ. This observation lends *support to Hypothesis 5*. The β-coefficient indicates that the widening of the pay gap by 1% results in a 0.0295% decrease in the positive influence of 1% employee pay growth on the ability to commercialise innovations measured by RQ. The motivation of workers is predominantly influenced by short-term benefits, which primarily comprise employee remuneration [36]. The average employee remuneration growth has been shown to be associated with the individual's behaviour and attitude to work processes, and ultimately has a positive impact on firm innovativeness. Nevertheless, the discrepancy in remuneration between CEOs and ordinary employees, characterised by a disproportionate increase in CEO compensation relative to that of ordinary employees, has been demonstrated to have a detrimental effect on the positive impact of employee remuneration and to impede the innovative capabilities of the company as a whole.

Conclusion and discussion

The present study investigates the relationship between the CEO-employee pay gap and company innovative-

Table 7. Analysis of industrial, regional and indirect effect of the pay gap

Variable	Model 6 – H3 (RE)	Model 7 – H4 (RE)	Model 8 – H5 (FE)
CEO-employee pay gap	–0.0265 (0.0370)	–0.0452 (0.0408)	–0.1180 (0.1139)
Industry	0.0869** (0.0414)		
CEO-employee pay gap·Industry	0.0451** (0.0227)		
Region		0.0236** (0.0104)	
CEO-employee pay gap·Region		0.0200** (0.0097)	
Employee pay growth			0.0784** (0.0380)
CEO-employee pay gap·Employee pay growth			–0.0295** (0.0132)
Market cap	0.0373* (0.0192)	0.0426** (0.0196)	0.0776 (0.1782)
ROA	0.4195* (0.2055)	0.4209* (0.2156)	0.4713** (0.2132)
Price-to-book	-0.0001 (0.0025)	-0.0002 (0.0025)	–0.0177 (0.0197)
Leverage	0.4360* (0.2256)	0.3881* (0.2302)	0.2575** (0.1026)
CEO pay growth	–0.0472 (0.0491)	–0.0444 (0.0490)	–0.0478 (0.0750)
Constant	0.5679*** (0.1983)	0.5816*** (0.1985)	0.7107** (0.3438)
Year dummies	Yes**	Yes**	Yes**
R^2	0.028	0.032	0.005
Number of firm-year observations	1188	1188	1188

Notes: Robust standard errors clustered by firm are provided in parentheses. Respective standard errors are presented in the brackets. Table 7 reports the RE specifications corresponding to Equations (6) and (7) and the FE specification for Equation (8).
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Authors' calculations.

ness, which is determined as the ability to commercialise innovative activities. The RQ is selected as a measure of firm innovativeness due to its universality and capacity to evaluate a company's aptitude for commercialising its innovations [32; 40].

The study offers empirical evidence demonstrating that the disparity between the remuneration of CEO and that of the wider workforce exerts a substantial deleterious effect on the innovative capacity of the firm. The vertical pay gap, which arises due to the higher increase in compensation of CEOs compared to ordinary employees, has been shown to have a detrimental effect on employees' efforts and behaviour towards collaboration and innovation. This, in turn, has a harmful effect on a company's ability to commercialise its R&D activities. This finding aligns with the social comparison and pay equity theories [13; 16].

In contrast to the findings reported by Mingli et al. [27], our research results did not support the U-shaped relationship between firm innovativeness and the pay gap. The results obtained have only confirmed the theory of social equality. However, the paper considers how this relationship differs depending on the technology intensity of the industry in which a firm operates. The findings demonstrate that the promotion incentives available to inventors are more prevalent in technology-intensive firms. Furthermore, the results indicate that the pay gap has a more beneficial effect on the innovativeness of technology-intensive firms than on non-technology-intensive firms. The theory of tournaments is thus applicable to companies characterised by a high degree of technological intensity. The predominance of inventor incentives, namely career promotion and pay raises, as well as the promotion of investment in innovations in technology-intensive industries, which are characterised by a significantly higher ratio of inventors on their staff, is the foundation for this argument.

A comparison of companies in developed European and Asian countries confirmed the findings of the tournament theory for companies operating in developed Asian countries and the pay equity and social comparison theories for companies operating in developed European countries. These results are consistent with the studies by Hofstede [25] and Nakata and Sivakumar [26]. According to Hofstede's theory, societies with a high rate of individualism, such as developed European countries, are characterised by employees who make decisions independently, pursuing personal benefits and self-realisation rather than those of the firm. This ambiguity may impede the innovative process by introducing an element of uncertainty, which can hinder the confidence and motivation of the research team. Concurrently, the protracted nature of R&D initiatives, characterised by a substantial degree of uncertainty and the potential for failure, contributes to the enhancement of firms' capabilities to commercialise their innovations within a collectivist society. This reduction can be attributed to the tendency of Asian employees to prioritise the long-term strategic interests of the firm over short-term benefits.

The study demonstrated that the widening of the pay gap served to moderate the positive relationship between employee pay growth and firm innovativeness. The phenomenon of remuneration inequality, precipitated by the disparity between the growth rate of CEO compensation and that of ordinary employees' remuneration, has been demonstrated to have a deleterious effect on employee motivation and to concomitantly diminish the innovative capacity of the company as a whole. This finding is consistent with the conclusions drawn by Rambo and Pinto [36] in their research.

The findings of this study carry significant policy and managerial implications. A comprehensive understanding of the influence of the CEO-employee pay gap on firm innovative capabilities is imperative for the development of an organisation's optimal incentive system, which is designed to promote innovativeness. It is imperative that such an incentive system be designed to achieve a balance between the motivation of top management to promote corporate innovation and the innovation impetus of the personnel. This balance must be achieved by taking into account the industrial and regional characteristics of a firm's operations.

The cultural dimensions of individualism, power distance and time orientation have been identified as distinctive features that contribute to the disparities in living standards between Asia and Europe. It is imperative that these fundamental factors, which elucidate the divergent attitudes of nations towards innovation, are given full consideration when determining the remuneration of employees and incentivising their innovation activity.

The incorporation of the pay gap factor into company investment analysis has the potential to enhance the efficacy of the analysis as a driver of innovative efficiency. This, in turn, will improve the accuracy and adequacy of investors' assessments of a firm's long-term sustainability and growth opportunities. The incorporation of data pertaining to the size and dynamics of the pay gap, employee pay growth, and industrial identity within the company's forecast framework will facilitate the determination of its valuation. Consequently, the findings of this study provide a valuable contribution to the formulation of a reliable investment strategy.

The present study is subject to certain limitations that could be addressed in future research. First, due to the unavailability of disaggregated data, the average compensation of rank-and-file employees is used as a proxy for the compensation of staff that is related to R&D activities. The same rationale underpinning the use of average compensation over median compensation is applicable in this context, with the latter potentially offering a more accurate reflection of an incentive structure. Secondly, the study's sample encompasses observations over a comparatively brief period and incorporates solely those public firms that voluntarily disclosed information pertaining to their R&D activities and compensation. These issues have the potential to result in bias with regard to sample selection. However, it should be noted that information disclosure requirements are subject to constant evolution, which will engender new opportunities for the enhancement of meth-

odology and sample construction. Additionally, measurement errors may be attributable to the indirect observation of employees' motivation. Finally, RQ is widely regarded as one of the most universally applicable metrics for measuring a company's innovativeness; however, it must be noted that it does not encompass all the dimensions of a company's innovativeness.

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The Analysis of Short-Selling Restrictions in Emerging Equity Markets

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Abstract

The spread of COVID-19 threatened worldwide financial stability and led to the introduction of short-selling restrictions in equity markets. Both developed and emerging markets tried to protect investors with these measures, aiming to support price levels and prevent market panic. In the modern literature there is no unequivocal opinion about the effect of short-selling restrictions on equity markets, moreover, most of the literature focuses on the USA and Europe, heeding no attention to the developing equity markets. For the first time in the literature this paper examines the effect of short-selling restrictions in emerging markets. In the paper, the analysis of restrictions on stock returns, volume of trade, liquidity, volatility, and market risk-metrics (Value-at-Risk and Expected Shortfall) is carried out. The study covers the period of financial turmoil in 2020, caused by the spread of COVID-19. The study is carried out separately for the two most popular restriction types: short-selling ban and uptick rule, which allows to compare these two policies. It is discovered that both the short-selling ban and the uptick rule have the same effect on equity markets in terms of size and significance of the effect. With a matched difference-in-difference framework, the study finds that the introduction of short selling restrictions leads to an increase in daily and weekly stock returns with no change in volume of trade or liquidity. In contrast with the results of previous studies, the volatility of stock returns decreases, leaving market risk measures (Value-at-Risk and Expected Shortfall) unchanged. The results are validated by several robustness checks: placebo tests, changes of matching schemes. The results of the study may help equity market regulators to understand the outcome of short selling restrictions on the stock market and influence their decisions regarding the type and duration of short-sale restrictions.

Keywords: equity market crash, short-selling bans, uptick rule

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Introduction

Among various regulatory measures employed during times of financial distress, the temporary ban on short selling stands out as one of the most frequently utilized approaches to mitigate market volatility. Since the 17th century, short sellers have been blamed for market slumps and crashes [1]. However, there is no unified answer to the question of whether a prohibition of short selling can restore market equilibrium. [2–4], and many others believe that this extreme measure stabilizes the equity market and supports price levels. However, [5; 6] support the opposite opinion: the policy is useless in preventing equity price downfall.

Worldwide implementation of short-selling restrictions during the financial crisis of 2008 and the COVID-19-related stock market fall in 2020 stir up the interest in the issue. However, the majority of studies focuses on the USA and Europe, paying no attention to the emerging markets. This leap seems inappropriate, since according to IMF[2], developing economies have shown a growth rate that is twice as high (in real terms) compared to developed countries over the last 20 years. IMF forecasts show that this trend will be preserved in the future, making investments into equity markets of emerging economies an attractive opportunity. A study by [7] demonstrates that emerging equity markets may offer investors a higher upside potential in terms of risk premia, which may additionally motivate them to consider this investment opportunity.

This research makes at least three significant contributions to the literature. First, it studies the impact of short-selling regulations in emerging markets. Moreover, it attempts to answer a commonly asked question: is the same policy equally useful in developed and developing equity markets or does is require changes to fit the needs of emerging economies? Secondly, due to different regulations introduced in developing countries, this study can compare the effectiveness of the short-selling ban and the uptick rule in terms of their influence on equity returns and market efficiency. Last but not least, this is an extension of the study by [8] of the influence of the short-selling ban on market risk metrics. This is almost ignored in modern literature, although the effect is crucial for bank-based systems.

Using an international panel of countries and introduction of short-selling restrictions during the 2020 market panic caused by COVID-19, this study examines the effect of regulation changes on daily and weekly equity returns, volume of trade, liquidity, weekly volatility and market risk metrics (measured by Value-at-Risk and Expected Shortfall). Different policies implemented around the world allow comparing the short-selling ban and the uptick rule and their influence on the market. Using the difference-in-difference approach (a modified version with several pre- and post-treatment periods) and matching on covariates, robust estimates of crisis regulation are obtained.

The study finds that short-selling regulation positively affected stock returns in the countries in question, had no effect on volume of trade and liquidity, but decreased the volatility of stock returns. VaR and ES were unaffected, which is the opposite effect to the one observed in Europe during the same period. Several placebo tests are carried out to verify the validity of the results and provide estimates for different horizons of analysis: there is no influence of pre-treatment period on estimates. Summing up, the difference between effects of policies in developed and emerging markets is detected. However, it turns out that the short-selling ban and the uptick rule result in approximately the same outcomes, making no difference in these policies. Therefore, a regulator may choose one that is better known to the equity market of its country. Finally, deterioration of market risk metrics was not detected, thus it cannot be claimed that the imposition of short-selling restrictions negatively affected the banking system.

The study is structured with a literature review in second section, methodological details and data description in third section, empirical findings, and discussion in fourth section, and concluding remarks in fifth section.

Related literature

A discussion of short-selling bans and their influence on equity markets has begun in the mid-20th century, resulting in two different branches in the literature: disarrangement theory and rational expectation framework. The former claims that a short-selling ban leads to overvaluation, while the latter refutes this statement. The disarrangement theory is supported by a seminal paper by [2]. He develops the framework of the Capital Asset Pricing model introduced by [9] and [10], relaxing the homogeneous belief assumption. He demonstrates that investors with pessimistic views are unable to trade in the presence of a short-selling ban. This fact does not allow negative information (pessimistic views) to be incorporated into stock prices. Since only investors with optimistic views are able to trade, they push the price of an asset upwards, leading to overvaluation of it. [11] confirms the findings of Miller's research. [3] proposes an alternative theory for asset overvaluation, attributing it to the speculative investor behaviour. The authors demonstrate that investors may engage in speculation, thus increasing the prices of assets. In the absence of short-selling, investors will acquire assets to sell them later to other investors who are more optimistic. [12] expand the ideas presented by [11] and create a theoretical model, proving that in the absence of short selling an appearance of market bubbles is possible due to investor overconfidence.

[5] disagree with Miller's conclusions. They find that with a rational expectations framework and a short selling ban, no overvaluation is present. They base their analysis on the order flow model of [13]. The paper states that rational investors know about the absence of short selling, thus take into account that negative information is excluded from

[2] URL: www.imf.org

equity prices. Consequently, investors decrease their valuation, preventing the absence of short sale from influencing asset prices. [14] demonstrate that imposing a short selling ban may result in a decline in equity prices. The authors develop a theoretical model of a market crash, which illustrates that the prohibition of short selling prevents negative information from being reflected in asset prices, leading to an even more severe price collapse when the market eventually crashes. [15] continue the analysis of [5] results but can prove them only partially. According to them, a short-selling ban leads to slower price discovery and higher risk premia, thus lowering the price of an asset. At the same time, the inability to short sell prevents investors from hedging, thus forcing them to buy more stocks and push the price upwards. It is unclear which of the effects will be dominant.

Based on these papers, a vast number of empirical studies were developed. [16] is among the first who tested the conclusions of [2]. He studies how the number of shorted stocks affects its return. The empirical analysis reveals that stocks characterized by minimal short interest (few market participants tend to short sell it) generate significantly higher abnormal returns than those experiencing substantial short selling activity among market participants. The absence of short selling impedes the market's ability to incorporate adverse information, resulting in unfairly high asset valuation. [17] confirm Miller's conclusion: a high short-selling constraint and divergence of opinions among investors lead to overvaluation. Empirical evidence presented in [6] indicates that stocks associated with substantial short selling costs display increased book-to-market values relative to their low-cost rivals, thus corroborating the overpricing hypothesis. [6] find that a stock that is expensive to short sell has a higher book-to-market ratio than one with a low cost of short-selling, which supports the overpricing hypothesis. [18] also show convincing evidence for Miller's conclusions. In their pioneering study, [19] demonstrate that the opportunity to engage in short selling accelerates the speed of price discovery, thereby contributing to a more efficient market. This work stands out as an early attempt to comprehensively analyse both stock returns and market efficiency.

The US Securities and Exchange Commission (hereafter, SEC) conducted a well-designed experiment on the issue. During 2005 and 2007, one-third of randomly selected Russell 3000 stocks was exempted from the uptick rule (formally known as Rule 10a-1). Although the regulatory change did not impact average daily volatility or liquidity, it resulted in a modest increase (4–5%) in short-selling volume [20]. According to studies [21] and [22], the elimination of the uptick rule across all US stocks on July 6, 2007 did not result in any notable price effects. Although a slight decline in liquidity was detected, it was not responsible for the increased volatility observed in July–August 2008.

A seminal study by [23], which analysed data from the 2008 financial crisis, reveals that short sale bans effectively supported price levels only in the United States, with no similar impact observed in other countries (the authors studied a dataset that contained 30 countries). The research also indicates negative consequences for market liquidity and price discovery. These conclusions are supported by [24] and [25]. Meanwhile, [26] question the efficacy of such bans, arguing that their adverse side effects surpass any potential benefits. In contrast, [27] observe a stabilizing influence from short sale restrictions. Further examination of the US equity market by [28] confirms that the ban did support price levels, though their findings may be confounded by a simultaneous government intervention through the Troubled Asset Relief Plan (TARP). The study also documents reduced trading volumes, widened bid-ask spreads, and heightened intraday volatility for stocks whose short sale was not allowed.

The COVID-19 crisis returned the attention to the issue as short-selling restrictions were imposed around the globe. Most of the papers study the short-selling ban and its effect on the European equity market, leaving the emerging markets uncovered, but the literature is still developing.

The analysis by [29] highlights divergent market responses to identical regulatory measures across European countries (all countries introduced a full short sale ban). France encountered overpricing, contrasting with the under-pricing observed in the Italian and Spanish equity markets.

[30] research expands on the theoretical model proposed by [5], offering empirical validation for previous results. The study confirms that imposing bans fails to prevent market crashes and is associated with lower stock returns and reduced liquidity. These findings are also confirmed by [31] and [32] who demonstrate that the ban failed to support the price level, but negatively affected volume, liquidity, and volatility. In contrast with this paper, a study by [33] shows that the ban was detrimental to market efficiency, but positively affected stock returns. The discrepancy in research outcomes can be explained by different analytical methods. The methodology utilized by [33] focuses on day-to-day returns as a measure of price recovery. The approach taken by [31] involves assessing abnormal returns through a specific metric—the daily difference between individual stock returns and market index performance of the same trading day. [32] analyses buy-and-hold returns vs. the Datastream Europe Total Market equity index.

To the best of the author's knowledge, the only paper that studies the influence of restrictions on short selling in developing markets is [34]. The authors analyse Thailand's equity market and find that the uptick rule destroyed the market depth and resulted in order imbalance.

To summarize, the scholarly community has yet to reach a unified view on the consequences of imposing short selling restrictions in equity markets. There are papers showing both positive and negative effects on stock prices during the restrictions from the theoretical and empirical points of view. Only the effect on market efficiency can be considered unequivocal: most papers point out that restrictions destroy liquidity, slow down price discovery and worsen trade volume. This paper contributes to the analysis in the literature in the following ways: it suggests the analysis of

the effect of short selling restrictions (short selling ban and uptick rule) on daily and weekly stock returns, as well as trading characteristics (daily volume of trade, weekly volatility, liquidity and range) and market risk (through the analysis of Value-at-Risk and Expected Shortfall) during 2020 in emerging markets.

Table 1. Worldwide Placement and Timing Structure of Short Sale Restrictive Measures

Region	Country	Dates	Policy type	Comment
Europe	Italy UK	13 March 2020	Target list ban	
	Belgium France Italy Spain UK	17 March 2020	Target list ban	
	Several EU members	18 March 2020 – 18 May 2020	Exchange-wide ban	Short-selling ban was implemented in Austria, Belgium, France, Greece, Italy, and Spain
Middle East	Turkey	28 February 2020 – 06 July 2020	Exchange-wide ban	As of 30 June 2020, the Istanbul Stock Exchange lifted restrictions on short selling for its top 30 shares. On 6 July 2020, the permission was extended to all market participants, with the exception of six major banks: Goldman Sachs Group Inc., JPMorgan Chase & Co., Merrill Lynch International LLC, Barclays Bank PLC, Credit Suisse Group AG, and Wood & Co. These banks remained under the short-selling ban until 12 December 2021.
	UAE	9 March 2020 to further notice	Exchange-wide ban	
South Asia	Pakistan	01 April 2020 – 30 April 2020	Uptick rule	The uptick rule was applied to thirty-six futures market shares only
	India	23 March 2020 – 28 August 2020	Short selling of index derivatives is prohibited	The ban was renewed several times: announced on 20d March 2020 it was effective from 23 March 2020 to 20 April 2020. On 20 April it was extended to 28 May 2020. Later it was extended to 30 July 2020.
Southeast Asia	Indonesia	02 March 2020 to further notice	Exchange-wide ban	
	Malaysia	24 March 2020 – 31 December 2020	Exchange-wide ban	The ban was renewed several times: announced on 23 March 2020, it was effective from 24 March 2020 to 28 April 2020. On 28 April 2020 it was extended to 30 June 2020. On 26 June 2020 it was extended to 30 December 2020. Announcement of removal was published on 16 December 2020, effective from 01 January 2021
	Thailand	13 March 2020 – 30 September 2020	Uptick rule	
East Asia	South Korea	13 March 2020 – 15 March 2021	Exchange-wide ban	The ban was extended on 27 August 2020 to 15 March 2021
	Taiwan	19 March 2020 – 10 June 2020	Uptick rule	

Source: Yale Program on Financial Stability (YPFS) Resource Library[3].

[2] URL: https://ypfs.som.yale.edu

Data and methodology

Timeline of events in 2020

Due to the applied type of this research, the chronology of events plays a vital role as it explains the choice of pre- and post-treatment periods. The initial spread of COVID-19 was traced back to Wuhan, China, in late 2019. On 30 January 2020, World Health Organization (WHO) classified the outbreak as a Public Health Emergency of International Concern, later declaring it a Pandemic on 11 March 2020. The collapse of equity markets in developed regions, notably Europe, began on 20 February after Italy reported its first COVID-19 cases [31; 32].

In the wake of the virus's global spread, financial regulators were required to deploy a spectrum of policy tools to uphold financial market stability. Table 1 provides a structured overview of short selling restrictions adopted across different jurisdictions.

The scope of this study is limited to examining the implications of regulatory measures adopted in emerging markets. As such, the EU's restrictions on short selling are not addressed in the paper. The effect of this restriction is discussed in many papers previously mentioned in literature review. In addition, India and Pakistan were not included in the sample due to several reasons. First, both countries prohibited the ban in derivative markets (short selling in equity markets was allowed). Second, including Pakistan would limit the period of the analysis after the change in regulation to only one month, which may lead to unreliable estimates.

Table 2. GDP per capita, USD 2015 constant prices

Treated group		Control group	
Country	**GDP per capita, $**	**Country**	**GDP per capita, $**
Indonesia	3851	**Japan**	36 044
Malaysia	10 903	**Mexico**	10 159
South Korea	31 646	**Russia**	9882
Turkey	12 074	**Saudi Arabia**	23 887
UAE	42 700	**Singapore**	61 334
Thailand	6 435	**Vietnam**	3 241
Taiwan	25 156		
Average	18 966	**Average**	24 091

Source: Compiled by the author based on the World Bank data.

Data description

The data are collected from Yahoo!Finance[4] and Compustat[5] databases. The following countries that introduced any short-selling restrictions in equity markets (the treated group, to be defined later) are included in analysis: Indonesia, Malaysia, South Korea, Turkey, the UAE, Thailand and Taiwan. The following set is selected as the control group: Japan, Mexico, Russia, Saudi Arabia, Singapore, Vietnam. According to the Morgan Stanley Capital International's market classification (MSCI market classification), all the countries that introduced the short-selling restrictions are considered emerging equity markets[6]. A country may consider itself developed but have an emerging equity market (e.g., South Korea). No econometric literature can offer a strict and clearly defined procedure for choosing a control group; hence this study attempted to select countries that are economically and geographically similar to the treated. To check the absence of significant economic difference, the author carried out a simple t-test of equality of mean, analyzing the GDP per capita in USD 2015 constant prices and discovered no significant difference.

[4] URL: http://finance.yahoo.com

[5] URL: http://www.compustat.com

[6] URL: https://www.msci.com/our-solutions/indexes/market-classification

The sample consists of daily stock market data. Key values such as 'Open', 'High', 'Close', 'Adjusted Close', 'Low', and 'Volume' are gathered. Constituents of the largest market indices in corresponding countries are selected (as of December 2019, pre-COVID period). If data is missing, it is not replaced by other stock (not from the index). Accounting fundamentals as of 31 December 2019 are collected for the purposes of matching. They include the following variables: earnings before interest, tax, depreciation, and amortization (EBITDA), net income (NI), long-term debt (LTD), total assets (TA), and equity, as well as the industry ID (according to Global Industry Classification Standard (GICS)). A summary of the stocks in the sample is presented in Table 2.

Table 3. Summary of stocks in the sample

Country	Index	Number of stocks	Country	Index	Number of stocks
Exchange-wide ban			**No restrictions on short selling**		
Indonesia	IDX 30	27	Japan	Nikkei 225	38
Malaysia	FTSE MYX	30	Mexico	BMV IPC	33
South Korea	KOSPI 50	41	Russia	MOEX	33
Turkey	BIST 30	29	Saudi Arabia	TASI	30
UAE	DFM	27	Singapore	FTSEST STI	25
Uptick rule			**Vietnam**	**VNM 30**	**11**
Thailand	SET 50	45			
Taiwan	FTSE TW50	48			
Total		247	Total		170

Source: Compiled by the author.

To account for the impact of COVID-19 prevention measures, the study incorporates the Stringency Index as a control variable. This data is gathered from the Oxford COVID-19 Government Response Tracker[7]. The index quantifies the strictness of government restrictions, ranging from 0 (no restrictions, pre-COVID conditions) to 100 (maximum stringency). It comprises three main categories: containment measures (including eight components such as school and workplace closures, public event restrictions, and movement limitations), economic support measures (four components), and healthcare system responses (five components covering testing, tracing, and vaccination). Detailed information on the variables and methodology is provided in [35].

Figure 1 presents the dynamics of the Stringency Index for the analysed countries between 1 January 2020 and 1 September 2020. The blue dashed lines mark the dates when WHO declared the emergency and pandemic status, respectively. Red lines denote the implementation and lifting of short-selling restrictions. The black dotted line indicates the start of the market crash on 20 February 2020.

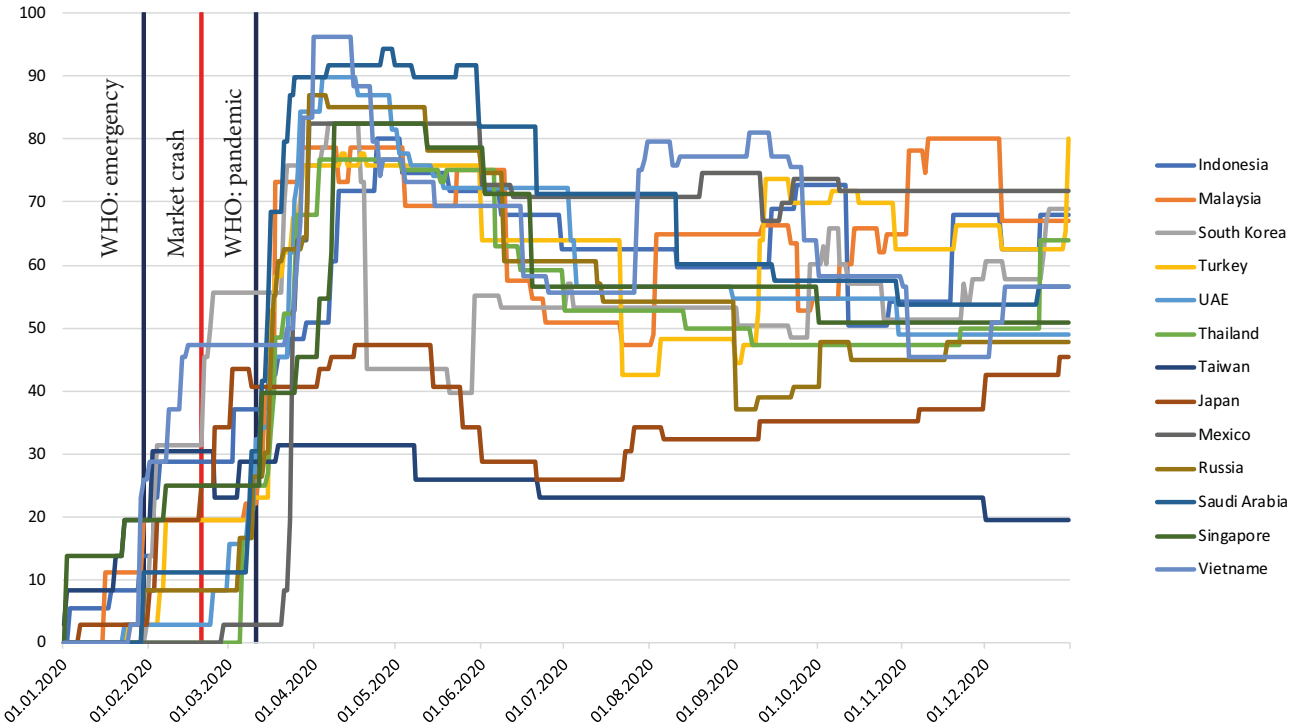
Dependent variables' description

This paper studies the effect of regulations on daily and weekly returns, volume of trade, liquidity, range, weekly volatility and two risk measures: VaR and ES.

Daily returns are calculated as the logarithm of the ratio of adjusted close price to the previous one, weekly returns are calculated as the logarithm of the ratio of Monday to Monday adjusted close price (or the first working day to the first working day of the subsequent trading week). Due to different currencies used across the sample, absolute characteristics are calculated in USD equivalent using the relevant exchange rate (such as volume and liquidity measures). Volume of trade is calculated as turnover multiplied by adjusted close in USD equivalent. There are two liquidity metrics in the paper: Amihud illiquidity measure [36] (the absolute value of the daily return divided by the trading volume in USD equivalent) and range measure (difference between high and low price divided by close price in USD equivalent). Volatility is calculated as standard deviation of daily returns in the same week and multiplied by 10^6 in order to increase the readability of the obtained results.

[7] URL: https://github.com/OxCGRT/covid-policy-dataset

Figure 1. Stringency Index Variation Among Countries



Source: Compiled by the author based on data from the Oxford Coronavirus Government Response Tracker.

Unfortunately, the author was unable to calculate the daily volatility as there was no access to intraday data. VaR and ES are calculated using the historical simulation method. A 250-day moving window is used for both risk metrics, and the confidence level is set to 1% in accordance with Basel III recommendations.

Methodology

To estimate the influence of the short-selling ban on equity markets, the difference-in-difference (DiD) methodology proposed by [37] was used. The framework requires two groups: treated and control, and at least two time periods (before and after treatment). In this study, the treatment variable represents a change in equity market regulation, specifically the implementation of either a short-selling ban or an uptick rule. The treated group comprises countries where these regulatory changes were introduced, while the control group includes countries that experienced no changes in their regulatory framework.

Length of pre- and post-treatment periods

Contrary to the initial paper of [37], this study uses several pre- and post-treatment time periods since there is daily data available. Therefore, it was necessary to select the length of those periods. Since there is no formal rule of defining the length, I base my solution solely upon the economic intuition.

Post-treatment period

For the treated group where a short-selling ban or an uptick rule were introduced, the start of post-treatment period is the date when the restrictions went into effect. For comparability purposes, the start of the post-treatment period for the control group is determined as the first day of the start of post-treatment in the treated group, i.e., during the analysis of the short-selling ban, the beginning of post-treatment period differed in each treated country (Indonesia, Malaysia, South Korea, Turkey and the UAE), but the corresponding control group is assumed to start the post-treatment period at the same time as Turkey (28 February 2020). The author considers this approach acceptable since international investors can start to behave differently, observing the change in regulation in neighbouring countries. The post-treatment period ends with the removal of restriction in any of the treated countries.

Pre-treatment period

Unlike the post-treatment period, the start of pre-treatment is solely a researcher's decision. On the one hand, it should be close to the treatment date (not to include any other significant events), on the other, it should be before any potential change in investors' behaviour could begin to occur. This study uses 1 December 2019 as the starting point for the analysis. By this time, COVID-19 had not yet begun to spread, but the date is close enough to the implementation of treatment. This choice balances the lengths of the pre- and post-treatment observation periods.

The baseline results are estimated based on the timeline presented in Table 3.

Table 4. Borders of pre- and post-treatment periods

Country	Pre-treatment period		Post-treatment period	
	Start	End	Start	End
Short-selling ban				
Indonesia	1 December 2019	1 March 2020	2 March 2020	30 June 2020
Malaysia	1 December 2019	23 March 2020	24 March 2020	30 June 2020
South Korea	1 December 2019	1 March 2020	2 March 2020	30 June 2020
Turkey	1 December 2019	27 February 2020	28 March 2020	30 June 2020
UAE	1 December 2019	8 March 2020	9 March 2020	30 June 2020
Control group	1 December 2019	27 February 2020	28 February 2020	30 June 2020
Uptick rule				
Taiwan	1 December 2019	18 March 2020	19 March 2020	10 June 2020
Thailand	1 December 2019	12 March 2020	13 March 2020	10 June 2020
Control group	1 December 2019	12 March 2020	13 March 2020	10 June 2020

Source: Compiled by the author.

Regression specifications

The model is estimated with a panel regression using the following regression specifications:

$$Y_{i,t} = \alpha_i + Time_{i,t} + Treatment_{i,t} + Interaction_{i,t} + \varepsilon_{i,t}; (1)$$

$$Y_{i,t} = \alpha_i + Time_{i,t} + Treatment_{i,t} + Interaction_{i,t} + Stringency_{i,t} + \varepsilon_{i,t}; (2)$$

$$Y_{i,t} = \alpha_i + Time_{i,t} + Treatment_{i,t} + Interaction_{i,t} + Stringency_{i,t} + Country_i + Constant + \varepsilon_{i,t}, (3)$$

where the following variables are used: $Y_{i,t}$ is dependent variable (parameter of interest of element , $Time_{i,t}$ is a dummy variable that takes values "1" for post-treatment period and "0" otherwise, $Treatment_{i,t}$, is a dummy variable that takes the value of "1" for treated units and "0" otherwise, $Interaction_{i,t}$ is a dummy variable equal to the result of multiplication of $Time_{i,t}$ and $Treatment_{i,t}$. $Stringency_{i,t}$ is a first-differenced Stringency index. $Country_i$ is a dummy variable for each country. α_i is an unobserved time-invariant individual effect. For the regressions (1)– (2), fixed effect estimation is used, for the regression (3) – the. pooling method. The key point of interest is the estimate and the significance of the *Interaction* variable, because only it bears the causal interpretation.

Matching on covariates

To address potential heterogeneity between the treatment and control groups, the study utilizes covariate matching techniques. This approach enhances the comparability of differences by achieving a covariate balance, where the distribution of covariates becomes comparable across both groups [38; 39]. The application of matching methods strengthens the robustness of causal inference in observational studies by reducing the reliance on model specifications [40]. The fundamental matching principle involves adjusting the weights of specific observations within the groups to make them more similar. Following the matching procedure, the samples become artificially closer in terms of the covariates selected by the researcher.

For the matching process in this study, the following control variables are employed: TA (total assets), EBITDA (earnings before interest, taxes, depreciation, and amortization), LTD (long-term debt), shareholder's equity or net assets, and the company's industry classification (based on the GICS list). Three matching techniques are used: nearest neighbour matching, optimal pair matching, and optimal full matching. Among these, optimal full matching proves to be the most effective. Further details regarding the matching outcomes are provided in the Appendix, subsection 'Matching results'.

Standard errors

The methodology for adjusting standard errors depends on the type of sample utilized in the analysis. In the case of a matched sample, the standard errors are applied in their original form without alterations. According to the research carried out by [41], classical standard errors maintain asymptotic validity provided that the matching process is conducted without replacement and the regression model is appropriately specified. When dealing with an unmatched sample, modifications were applied to the standard errors following the recommendations found in relevant literature (see paper by [31]). The approach incorporates robust standard errors. From among various options available in econometric literature, the study uses the double clustered standard errors introduced by [42], similarly to the methodology employed by [28]. The technique suggested by [42] integrates the standard errors proposed by [43] and [44], implementing clustering at both the daily and country levels. This method ensures robustness against heteroskedasticity and serial correlation [45]. The consideration of serial correlation is especially crucial given that the analysis utilizes a within estimator framework, which inherently induces serial correlation [46].

In the context of regression analysis aimed at assessing the regulatory impact on market risk measures (Value at Risk and Expected Shortfall), a specific approach to standard error correction is applied. Given that the dependent variable itself is an estimate, it is necessary to adjust the standard errors to incorporate estimation uncertainty. The true value of risk metrics being unobservable, estimation is performed using multiple models, with no certainty regarding the correctness of any particular model. For instance, when estimating VaR, the following equation is utilized: $VaR_{i,t} = \widehat{Var}_{i,t} + \varepsilon_{i,t}$, where the estimated values of $\widehat{Var}_{i,t}$ are subsequently used as the dependent variable in further analysis. The nature of the error term $\varepsilon_{i,t}$ remains unknown, including its potential heteroscedasticity, autocorrelation, or correlation with errors from other VaR forecasts. To address this uncertainty, bootstrapped standard errors are employed. According to [47], in cases where the dependent variable is estimated, White OLS standard errors provide an adequate solution. However, the literature lacks studies specifically addressing this issue within the framework of panel data. To tackle this gap, a moving block bootstrap method proposed by [48] is implemented, utilizing a fixed block length of 10.

Results and discussion

Before proceeding to the discussion of results, let us recall that this paper examines three hypothesis.

- Hypothesis one. Developed and emerging markets have the same reaction to short-selling restrictions
- Hypothesis two. A short-selling ban is a stricter restriction than an uptick rule, therefore, it is more detrimental to market efficiency
- Hypothesis three. Short-selling restrictions negatively affect market risk metrics, thus making banks more vulnerable to equity price changes.

The effects of short-selling ban and uptick rule are estimated separately, otherwise, it is impossible to address the second hypothesis. The data is divided into two samples: the first sample is the treated group, comprising the countries where the short-selling ban was introduced

Table 5. Influence of short-selling restrictions on daily returns

Dependent variable:	Daily return					
Specification:	(1)		(2)		(3)	
Sample:	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched
Short selling ban						
Interaction	0.00252***	0.00275***	0.00212***	0.00244***	0.00209**	0.00241***
	(0.00081)	(0.00085)	(0.00081)	(0.00086)	(0.00081)	(0.00086)
Uptick rule						
Interaction	0.00307****	0.00378****	0.00308****	0.00377****	0.00305****	0.00374****
	(0.00068)	(0.00070)	(0.00068)	(0.00070)	(0.00068)	(0.00079)
Stringency	No	No	Yes	Yes	Yes	Yes
Country	No	No	No	No	Yes	Yes
Constant	No	No	No	No	Yes	Yes

Note: *p < 0.1; **p < 0.05; ***p < 0.01; ****p < 0.001.
Source: Compiled by the author.

Table 6. Influence of short-selling restrictions on weekly returns

Dependent variable:	Weekly return					
Specification:	(1)		(2)		(3)	
Sample:	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched
Short selling ban						
Interaction	0.01676****	0.01777****	0.01578****	0.01644****	0.01563****	0.01629****
	(0.00401)	(0.00426)	(0.00402)	(0.00430)	(0.00397)	(0.00433)
Uptick rule						
Interaction	0.00817**	0.01032***	0.00730**	0.00908***	0.00719**	0.00898***
	(0.00334)	(0.00321)	(0.00334)	(0.00321)	(0.00329)	(0.00320)
Stringency	No	No	Yes	Yes	Yes	Yes
Country	No	No	No	No	Yes	Yes
Constant	No	No	No	No	Yes	Yes

Note: *p < 0.1; **p < 0.05; ***p < 0.01; ****p < 0.001.

Source: Compiled by the author.

(Indonesia, Malaysia, South Korea, Turkey, and the UAE) and the control group; the second sample included the treated group, comprising countries where the uptick rule was introduced (Taiwan and Thailand) and the control group. For both samples, the control group is the same, but the matching is done separately, which results in different balance and weights. All the regressions are estimated separately for both subsamples.

The results of the estimation of regression specifications (1)–(3) are presented in Tables 4–11. Each table is devoted to a specific dependent variable, noted in the top part of the table, and includes the estimates of coefficient *Interaction* , since it is the only one to bear causal interpretation. Each table is divided vertically into three parts, one for each specification, and subdivided for matched and unmatched estimation results. Both are

Table 7. Influence of short-selling restrictions on volume of trade

Dependent variable:	Volume of trade, USD					
Specification:	(1)		(2)		(3)	
Sample:	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched
Short selling ban						
Interaction	−379,046,773	−347,700,168	−343,414,004	−319,306,315	−342,657,183	−318,696,338
	(272,044,872)	(252,113,213)	(272,462,045)	(249,943,547)	(496,897,268)	(438,431,263)
Uptick rule						
Interaction	−15,016,917	−152,298,520	−15,176,084	−151,963,160	−15,109,184	−151,999,939
	(102,578,125)	(259,846,008)	(102,579,019)	(259,812,475)	(190,687,756)	(485,860,710)
Stringency	No	No	Yes	Yes	Yes	Yes
Country	No	No	No	No	Yes	Yes
Constant	No	No	No	No	Yes	Yes

Note: *p < 0.1; **p < 0.05; ***p < 0.01; ****p < 0.001.

Source: Compiled by the author.

Table 8. Influence of short-selling restrictions on Amihud's illiquidity measure

Dependent variable:	Amihud's illiquidity ×10⁶					
Specification:	(1)		(2)		(3)	
Sample:	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched
Short selling ban						
Interaction	1.13897 (1.09474)	0.92096 (1.03786)	1.13619 (1.09649)	0.92141 (1.03493)	1.13614 (1.09908)	0.92183 (1.03999)
Uptick rule						
Interaction	−0.00975 (0.02180)	−0.07273 (0.05898)	−0.00979 (0.02180)	−0.07265 (0.05894)	−0.00976 (0.02273)	−0.07252 (0.06157)
Stringency	No	No	Yes	Yes	Yes	Yes
Country	No	No	No	No	Yes	Yes
Constant	No	No	No	No	Yes	Yes

Note: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$; $^{****}p < 0.001$.

Source: Compiled by the author.

reported to confirm additional robustness of the results and to highlight the influence of matching. Horizontally, each table is divided into two parts: one for the coefficient from the short-selling ban sample, the other for the coefficient from the uptick rule sample. On the bottom of the table, there is an indication of whether any additional variables or constants are included. Standard errors are given in parentheses, the significance level is indicated with stars (*). The results are as follows: irrespective of the specific restriction imposed (short-selling ban or uptick rule), the significance and direction of influence almost always coincide.

Significant positive influence on stock returns was detected both on the daily and weekly levels. This fact indicates that a change in market regulation speeds up the growth of equity prices in the treated group in contrast to the control group, thus making it higher. As for the trade volume, no significant change was detected in ei-

Table 9. Influence of short-selling restrictions on range

Dependent variable:	Range					
Specification:	(1)		(2)		(3)	
Sample:	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched
Short selling ban						
Interaction	−0.00314**** (0.00045)	−0.00340**** (0.00042)	−0.00237**** (0.00045)	−0.00278**** (0.00042)	−0.00233**** (0.00047)	−0.00273**** (0.00044)
Uptick rule						
Interaction	−0.00533**** (0.00056)	−0.00527**** (0.00057)	−0.00537**** (0.00055)	−0.00526**** (0.00056)	−0.00519**** (0.00057)	−0.00508**** (0.00059)
Stringency	No	No	Yes	Yes	Yes	Yes
Country	No	No	No	No	Yes	Yes
Constant	No	No	No	No	Yes	Yes

Note: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$; $^{****}p < 0.001$.

Source: Compiled by the author.

Table 10. Influence of short-selling restrictions on weekly volatility

Dependent variable:	Weekly volatility ×10⁶					
Specification:	(1)		(2)		(3)	
Sample:	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched
Short selling ban						
Interaction	−6,936.1**** (1,376.9)	−7,547.9**** (1,552.7)	−5,767.0**** (1,378.2)	−6,610.7**** (1,583.1)	−5,779.0**** (1,391.2)	−6,618.2**** (1,640.0)
Uptick rule						
Interaction	−5,279.3**** (830.9)	−5,070.0**** (838.4)	−5,359.9**** (809.0)	−5,021.2**** (818.3)	−5,198.4**** (834.8)	−4,853.6**** (864.2)
Stringency	No	No	Yes	Yes	Yes	Yes
Country	No	No	No	No	Yes	Yes
Constant	No	No	No	No	Yes	Yes

Note: p < 0.1; ** p < 0.05; *** p < 0.01; **** p < 0.001.

Source: Compiled by the author.

ther the short-selling ban or the uptick rule group. This is an interesting outcome: in similar conditions, the short-selling ban in the EU led to a lower trade volume. More research is required to explain the reason for this difference.

Liquidity metrics also behave differently: there is no significant increase in Amihud's illiquidity, but the range measure became smaller. This fact may indicate that the gap between the high and low prices, normalised by close, becomes smaller, thus indicating lower intraday volatility. This suggestion can be formally confirmed by the detected decrease of weekly volatility in both samples. On the contrary to the EU countries, who either experience no change or an increase in weekly volatility, short-selling restrictions actually decreased it in emerging markets. This effect may be seen as positive since a decrease in volatility may be equated with a decrease in overall risk (volatility is usually used as an approximate proxy of risk).

Table 11. Influence of short-selling restrictions on Value-at-Risk

Dependent variable:	VaR, historical simulation					
Specification:	(1)		(2)		(3)	
Sample:	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched
Short selling ban						
Interaction	0.00187 (0.01894)	0.00217 (0.01652)	0.00197 (0.01906)	0.00227 (0.01659)	0.00158 (0.01901)	0.00189 (0.01656)
Uptick rule						
Interaction	−0.00568 (0.01045)	−0.00485 (0.01765)	−0.00568 (0.01045)	−0.00485 (0.01765)	−0.00539 (0.01042)	−0.00462 (0.01758)
Stringency	No	No	Yes	Yes	Yes	Yes
Country	No	No	No	No	Yes	Yes
Constant	No	No	No	No	Yes	Yes

Note: * p < 0.1; ** p < 0.05; *** p < 0.01; **** p < 0.001.

Source: Compiled by the author.

Table 12. Influence of short-selling restrictions on Expected Shortfall

Dependent variable:	ES, historical simulation					
Specification:	(1)		(2)		(3)	
Sample:	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched
Short selling ban						
Interaction	−0.00562 (0.01086)	−0.00472 (0.00960)	−0.00560 (0.01093)	−0.00471 (0.00964)	−0.00602 (0.01090)	−0.00511 (0.00963)
Uptick rule						
Interaction	−0.00509 (0.00795)	−0.00436 (0.00966)	−0.00509 (0.00795)	−0.00436 (0.00966)	−0.00479 (0.00793)	−0.00412 (0.00963)
Stringency	No	No	Yes	Yes	Yes	Yes
Country	No	No	No	No	Yes	Yes
Constant	No	No	No	No	Yes	Yes

Note: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$; $^{****}p < 0.001$.

Source: Compiled by the author.

In paper by [8], a lot of attention is paid to the importance of tail risk in equity markets. He explains that an increase in tail risk, caused by short-selling restrictions, may negatively affect a bank's capital adequacy ratios. Following this suggestion, the study tests the influence of the short-selling ban and the uptick rule on Value-at-Risk and Expected Shortfall and find that neither metric changed significantly after the implementation of short-selling restrictions. As already mentioned, this is a partially expected result as the volatility in the corresponding period decreased, and the volume of trade and the illiquidity measure remained unaffected. All together, these three variables lay the ground for the conclusion that the overall market risk was not affected by the restrictions; therefore, one may expect no change in the risk metrics. This difference is one of the main ones between the reaction of emerging and developed equity markets to short-selling regulations.

However, this paper cannot suggest an explanation of the observed phenomenon, namely, why the volume of trade and liquidity were not affected by the restrictions in emerging markets? This issue remains unanswered and further research should be carried out. One of the possible hypotheses suggested by the author is that one may expect investors to move to less risky assets (such as bonds or money market instruments in reserve currencies) during financial crisis. However, investors in emerging markets may face higher transaction costs of switching from the risky equity market to the less risky bond market. Alternatively, the trading volume in emerging markets does not allow investors to quickly rebalance their portfolio, forcing them to keep their positions unchanged. Consequently, after the implementation of the ban, no large movement in the portfolios of the investors occurs due to these shortcomings, leaving the volume and, hence, risk unchanged. Another hypothesis that may explain the issue at hand is that developed and emerging equity markets differ in the proportion of wholesale and retail investors, or the proportion of local and foreign investors, which may result in different investor behavior patterns.

As for the difference between the short-selling ban and the uptick rule, it cannot be stated that either of the metrics is more or less influential since the estimates have the same direction and significance of the effect, and the estimates are close to each other numerically.

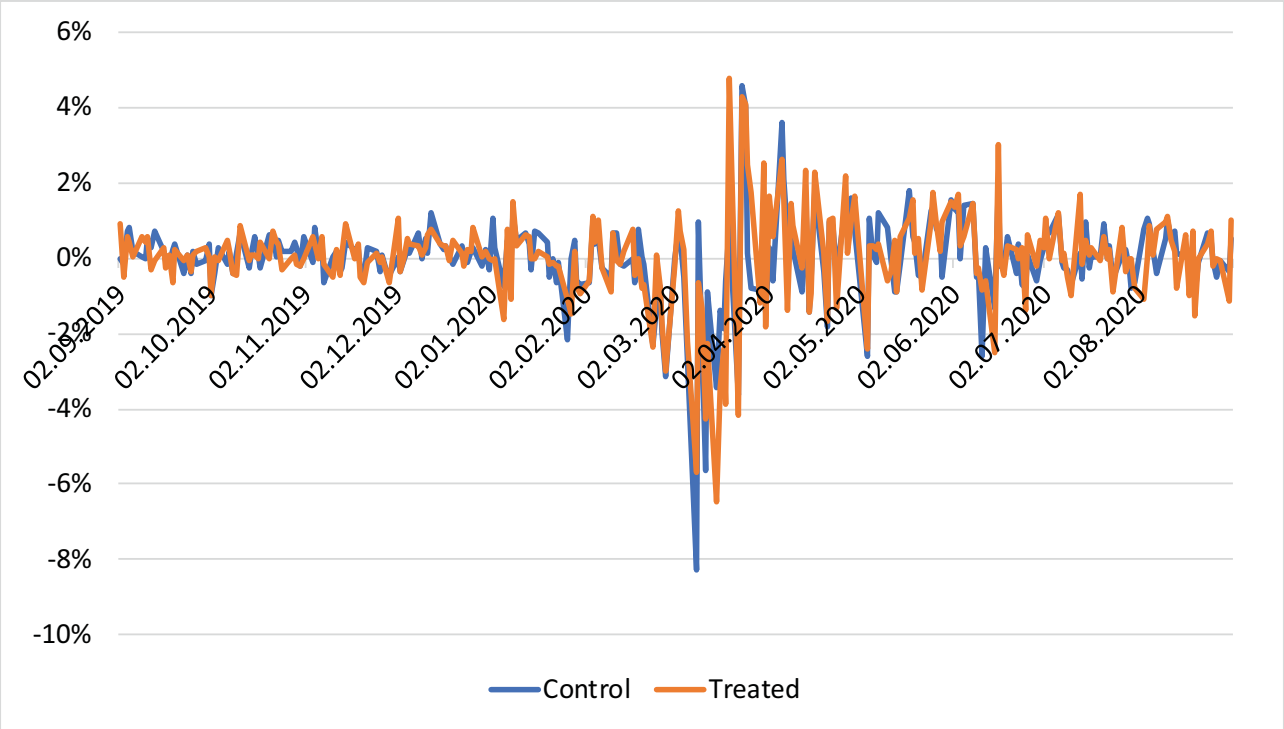
However, certain disclaimers about the limitations of this research need to be made. First, the results about the uptick rule introduction should be extrapolated very carefully since only two countries with limited number of stocks are studied. Second, the sample lacks intraday data, which, if present, would allow assessing more sophisticated metrics and studying their behaviour.

Robustness checks

The fundamental assumption underlying the DiD approach is the assumption of parallel trends. This posits that, in the absence of regulatory changes, both the treatment group (entities subject to the ban) and the control group (non-banned entities) would exhibit similar behavioural patterns. This critical assumption, commonly referred to as the 'parallel trends' condition, frequently sparks intense scholarly discussions, as evidenced by the debate surround-

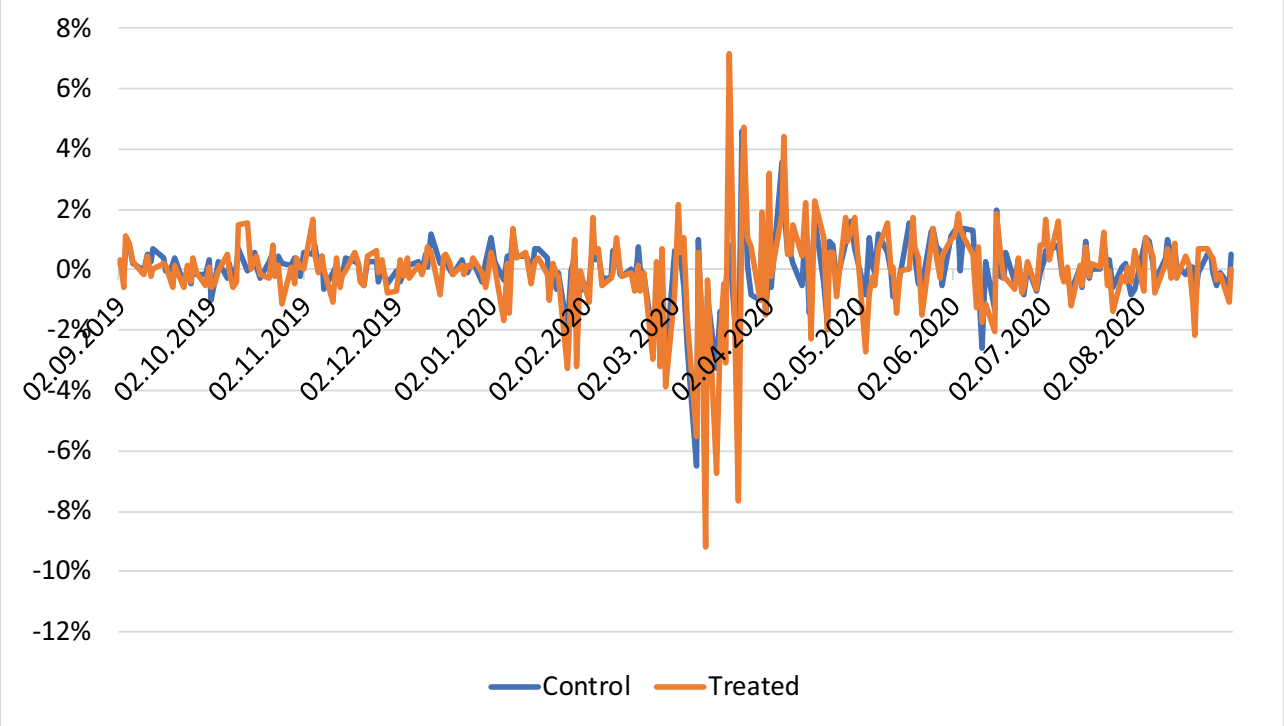
ing the work of [49] as critiqued in [50]. To validate this assumption, a two-pronged approach is employed. First, a visual examination of the variable's behaviour prior to the intervention is conducted. Second, formal statistical tests are performed to assess the significance of any observed differences. The graphical analysis presented in Figures 2 and 3 (short-selling ban and uptick rule subsets are studied separately) demonstrates that there are no notable disparities in the behaviour of daily returns between the treatment and control groups during the pre-treatment period. The rest of the variables can be found in the Appendix, subsection 'Robustness checks'.

Figure 2. Average daily returns in treated (short selling ban) and control groups



Source: Compiled by the author.

Figure 3. Average daily returns in treated (uptick rule) and control groups



Source: Compiled by the author.

Additionally, the author tested the difference between returns in groups against the time trend to detect any significant change but found no evidence for it.

A more formal approach to robustness of DiD methodology (and specifically parallel trend assumption) is a placebo test. It virtually sets a fake treatment date before the actual treatment had taken place and estimates the same regression specifications. Under the assumption of parallel trends, one might expect the interaction term in the DiD model to be statistically insignificant, as there is no policy change and thus no change in outcomes if the trends are indeed parallel. However, it is important to note that relying solely on the insignificance of the interaction term can be misleading. As highlighted by [51], this approach may be problematic due to the low statistical power of such tests. A non-significant result does not necessarily imply that the parallel trends assumption holds true. Therefore, instead of relying exclusively on statistical tests, it is crucial to provide robust logical reasoning and substantive arguments to support the plausibility of the parallel trends assumption. This involves presenting a compelling case based on economic theory, institutional knowledge, and the specific context of the study to justify why parallel trends are reasonable to expect in the absence of treatment.

I have carried out several placebo tests within the timeline of the study, shown in Table 12, and *Interaction* turns out to be insignificant. Placebo tests were carried out for both types of restrictions: short-selling ban and uptick rule.

Based on the placebo tests and visual diagnostics, the author found no evidence against the parallel trends assumption.

Another debatable point is the choice of the starting point of the pre-treatment period. Let us recall that in this paper all estimates are made for the case when the pre-treatment period begins 1 December 2019 (due to several reasons mentioned in third section). However, it is a question of whether the estimation results are sensitive to the change of the starting point. To answer this question, regressions for four additional starting dates (1 October 2019, 1 November 2019, 1 January 2020, 1 February 2020) were re-estimated, keeping the treatment date and the end of the post-treatment period unchanged. It turns out that almost no change in significance and the direction of effect can be detected. The estimates of the variable *Interaction* are presented in the Appendix, subsection 'Robustness checks': in Table 19 for the short-selling ban and in Table 20 for the uptick rule.

Table 13. Placebo pre- and post-treatment periods

Placebo №	Pre-treatment period	Post-treatment period
1	1 November 2019 – 31 December 2029	1 January 2020 – 28 February 2020
2	1 September 2019 – 30 November 2029	1 December 2020 – 28 February 2020
3	1 September 2019 – 30 November 2029	1 December 2020 – 31 January 2020

Table 14. Influence of short-selling restrictions on buy-and-hold returns

Dependent variable:	Buy-and-hold returns	
Specification:	(1)	(3)
Short-selling ban		
Interaction	0.20236**** (0.02752)	0.20034**** (0.02864)
Uptick rule		
Interaction	0.18879**** (0.05660)	0.18891**** (0.05502)
Stringency	No	No
Country	No	No
Constant	No	No

Note: *p < 0.1; **p < 0.05; ***p < 0.01; ****p < 0.001.

Source: Compiled by the author.

Modern literature disputes the effect of short-selling regulations on stock returns. Due to the fact that different approaches to this issue are used in terms of return calculation, to verify the study's research conclusions the author additionally calculated the returns from the buy-and-hold strategy (purchase of an asset in the beginning of the pre- or post-treatment period, and sale – at its end). For both samples, the effect of short-selling restrictions was discovered to be positive and significant. The estimates of the variable *Interaction* in such tests are shown in Table 13; the complete results of the regression estimations are presented in the Appendix, subsection 'Robustness checks'. In fact, this is classical DiD analysis, developed by [37]: only two groups and only two time periods.

Following the suggestion of one of the anonymous reviewers, the author also modified the matching strategy as well and used it separately. Instead of Total Assets Market Capitalization as of the end of December (depending on last trade date) were used, and matching and all the regression analysis were repeated. First, it is necessary to point out that in that case, the nearest matching turns out to dominate

the full matching (in terms of suggesting a better balance). Second, the results of the analysis remain the same: coefficients from Tables 5–12 change insignificantly. Therefore, this additionally proves the robustness of the results.

Summing up, the author may state that the results of this study are robust due to variance methodologies used (matching, double clustered standard errors) and additional tests (placebo studies, visual diagnostics).

Conclusion

This paper is devoted to the analysis of the effect of short-selling regulation on equity markets in emerging economies. The existing literature pays a lot of attention to scrutinising developed markets and their behaviour amid such regulation, but almost no one studies developing markets. Analysing developing equity markets is important as they may offer higher growth rates, which makes investment into their assets attractive. However, no one tries to address the issue of whether the application of the same policy in the developing markets produces the expected outcome. Moreover, almost no study has ever compared different types of short-selling regulations: the short-selling ban and the uptick rule.

In 2020, after COVID-19 had spread around the world, many countries tried to protect their equity markets from extreme downfalls and introduced the short-selling ban or the uptick rule. Meanwhile, other countries did nothing, which allows studying this case with a difference-in-difference approach. The influence of short-selling regulations on daily and weekly stock returns, volume of trade, liquidity, range and weekly volatility and market risk-metrics (Value-at-Risk and Expected Shortfall) is analysed. For additional robustness, covariate matching is used to improve the sample balance and double-clustered standard errors.

I use several regression specifications, but the results turn out to be similar. First, both regulations affect the variables of interest in the same direction, and neither one produces a greater effect. Second, a positive effect of short-selling ban on equity returns was detected, which supports the rationale for such a severe restriction. No influence on volume of trade and liquidity was detected, but there was a decrease in weekly volatility. No influence of short-selling regulations on market risk metrics was observed. This result partially contradicts the outcome observed in Europe during the short-selling ban implemented at the same time. This difference also highlights the importance of studying the emerging markets.

Additionally, several robustness checks were carried out: a placebo study was performed, confirming the validity of the DiD methodology. Regression estimated with various pre-estimation time periods were presented to ensure the absence of dependence of the results on the choice of time period.

The research can be developed in several ways. First, an analysis that would explain the difference between the reaction of trading volume and volatility in developed and emerging markets to the implementation of short-selling restrictions would enrich the understanding of equity market behavior. Second, the inclusion of other developing countries that used restrictions other than the short-selling ban or the uptick rule could be useful for the analysis of the issue. This can potentially enrich the understanding of the mechanics of short-selling regulation depending on its type. Third, one of the anonymous reviewers suggested an interesting idea: even though the short selling restrictions may be helpful in the short term, the lift of the restriction may cause a market correction, revealing the artificial (or even fake) positive image of market stability. Hence one should also study the effect of lifting the restrictions and the market reaction to it as well.

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Appendix

Matching results

The matching is done based on fundamentals as of 31 December 2019: TA (total assets), EBITDA (earnings before interest tax depreciation and amortisation), LTD (long-term debt), shareholder's equity or net assets and industry of the company (using the GICS list). All values are translated into USD equivalent. The unmatched sample demonstrates that its balance may be improved:

Table 15. Balance of unmatched sample for short-selling ban

Covariate	Treated mean	Control mean	Std. mean diff.	Var. ratio	eCDF mean	eCDF max
TA	37382.1	107735.2	-0.8825	0.0440	0.1126	0.2163
EBITDA	1991.4	5027.6	-0.6730	0.0791	0.1273	0.1989
NI	573.2	2081.7	-1.0441	0.0377	0.1244	0.1892
LTD	5487.5	17225.9	-0.7049	0.0553	0.1070	0.1769
Equity	8177.0	17728.0	-0.4783	0.2936	0.1018	0.1567
GICS10	0.0649	0.0529	0.0487	.	0.0120	0.0120
GICS15	0.1429	0.1235	0.0552	.	0.0193	0.0193
GICS20	0.1558	0.1471	0.0242	.	0.0088	0.0088
GICS25	0.0649	0.0588	0.0248	.	0.0061	0.0061
GICS30	0.1039	0.0882	0.0513	.	0.0157	0.0157
GICS35	0.0195	0.0412	-0.1570	.	0.0217	0.0217
GICS40	0.2532	0.2471	0.0142	.	0.0062	0.0062
GICS45	0.0390	0.0353	0.0190	.	0.0037	0.0037
GICS50	0.0714	0.0882	-0.0653	.	0.0168	0.0168
GICS55	0.0519	0.0471	0.0220	.	0.0049	0.0049
GICS60	0.0325	0.0706	-0.2151	.	0.0381	0.0381

Source: Author's calculations.

Table 16. Balance of unmatched sample for uptick rule

Covariate	Treated mean	Control mean	Std. mean diff.	Var. ratio	eCDF mean	eCDF max
TA	32 608.9	107 735.2	–1.3198	0.0225	0.0719	0.1507
EBITDA	1365.5	5027.6	–1.4422	0.0250	0.1320	0.2789
NI	647.2	2081.7	–1.1191	0.0297	0.0892	0.2414
LTD	2399.5	17 225.94	–5.4290	0.0015	0.0743	0.1953
Equity	5964.3	17 728.0	–1.4422	0.0490	0.0961	0.2202
GICS10	0.0538	0.0529	0.0036	.	0.0008	0.0008
GICS15	0.0968	0.1235	–0.0905	.	0.0268	0.0268
GICS20	0.0860	0.1471	–0.2177	.	0.0610	0.0610
GICS25	0.0860	0.0588	0.0970	.	0.0272	0.0272

Covariate	Treated mean	Control mean	Std. mean diff.	Var. ratio	eCDF mean	eCDF max
GICS30	0.0860	0.0882	–0.0079	.	0.0022	0.0022
GICS35	0.0215	0.0412	–0.1356	.	0.0197	0.0197
GICS40	0.2258	0.2471	–0.0508	.	0.0213	0.0213
GICS45	0.1828	0.0353	0.3816	.	0.1475	0.1475
GICS50	0.0645	0.0882	–0.0965	.	0.0237	0.0237
GICS55	0.0645	0.0471	0.0711	.	0.0175	0.0175
GICS60	0.0323	0.0706	–0.2169	.	0.0383	0.0383

Source: Author's calculations.

Note: The abbreviation 'eCDF' stands for 'empirical cumulative distribution function.' The GICS codes represent the economic sectors: 10 – energy, 15 – materials, 20 – industrials, 25 – consumer discretionary, 30 – consumer staples, 35 – health care, 40 – financials, 45 – information technology, 50 – communication services, 55 – utilities, and 60 – real estate.

The study uses nearest neighbour, optimal pair and optimal full matching. The last one turns out to be the best. Its resulting balance is presented in Tables 17 and 18 for the short-selling ban and the uptick rule, respectively.

It is apparent that after matching, the means in the treated and control groups almost coincide and the standardised mean difference is close to zero, which indicates a good balance.

Table 17. Balance of matched sample for short-selling ban

Covariate	Treated mean	Control mean	Std. mean diff.	Var. ratio	eCDF mean	eCDF max	Std. Pair Dist.
TA	37 382.1	34404.6	0.0374	0.3344	0.0474	0.1158	1.1098
EBITDA	1991.4	2089.8	–0.0218	0.5861	0.0501	0.1269	0.8778
NI	573.2	645.2	–0.0498	0.2786	0.0371	0.1190	0.9250
LTD	5487.5	5228.1	0.0156	0.4243	0.0473	0.1182	1.0439
Equity	8176.9717	8934.0957	–0.0379	1.2569	0.0238	0.0844	0.6698
GICS10	0.0649	0.0750	–0.0408	.	0.0101	0.0101	0.1933
GICS15	0.1429	0.1481	–0.0150	.	0.0053	0.0053	0.3810
GICS20	0.1558	0.1882	–0.0892	.	0.0324	0.0324	0.5777
GICS25	0.0649	0.0411	0.0966	.	0.0238	0.0238	0.4445
GICS30	0.1039	0.0990	0.0161	.	0.0049	0.0049	0.4214
GICS35	0.0195	0.0261	–0.0482	.	0.0067	0.0067	0.1378
GICS40	0.2532	0.2368	0.0379	.	0.0165	0.0165	0.6570
GICS45	0.0390	0.0281	0.0559	.	0.0108	0.0108	0.4676
GICS50	0.0714	0.0638	0.0294	.	0.0076	0.0076	0.5177
GICS55	0.0519	0.0747	–0.1024	.	0.0227	0.0227	0.3862
GICS60	0.0325	0.0190	0.0759	.	0.0135	0.0135	0.4030

Source: Author's calculations.

Table 18. Balance of matched sample for short-selling ban

Covariate	Treated mean	Control mean	Std. mean diff.	Var. ratio	eCDF mean	eCDF max	Std. Pair Dist.
TA	32 608.9	25 426.5	0.1262	0.2045	0.0782	0.1697	1.6398
EBITDA	1365.5	1790.7	–0.1674	0.2573	0.0525	0.1352	1.3919
NI	647.2110	817.4742	–0.1328	0.2890	0.0515	0.1487	1.4998
LTD	2399.4679	2741.0920	–0.1251	0.0170	0.1440	0.3000	5.5350
Equity	5964.2848	6785.9264	–0.1007	0.3239	0.0360	0.1333	1.3997
GICS10	0.0538	0.0811	–0.1211	.	0.0273	0.0273	0.5655
GICS15	0.0968	0.0808	0.0542	.	0.0160	0.0160	0.5695
GICS20	0.0860	0.1122	–0.0935	.	0.0262	0.0262	0.6732
GICS25	0.0860	0.0517	0.1223	.	0.0343	0.0343	0.2547
GICS30	0.0860	0.1620	–0.2709	.	0.0760	0.0760	0.6914
GICS35	0.0215	0.0323	–0.0743	.	0.0108	0.0108	0.3165
GICS40	0.2258	0.1384	0.2090	.	0.0874	0.0874	0.6345
GICS45	0.1828	0.2043	–0.0556	.	0.0215	0.0215	0.3960
GICS50	0.0645	0.0493	0.0620	.	0.0152	0.0152	0.5815
GICS55	0.0645	0.0661	–0.0063	.	0.0015	0.0015	0.2907
GICS60	0.0323	0.0219	0.0588	.	0.0104	0.0104	0.5775

Source: Author's calculations.

Different pre-treatment periods

As mentioned in fourth section, the choice of the start of pre-treatment period is subject to the researcher's decision, which may affect the resulting estimations. To avoid the accusations of data mining, four different additional starting dates are used. The estimation of the variable *Interaction* is presented in the next two tables for all regression specifications. It can be clearly seen that the estimates are in line with the one reported in the main part of the article, hence, the result does not depend on the choice of the starting point.

Table 19. Regression estimates for short-selling ban by starting date

Specification:	(1)		(2)		(3)	
Sample:	**Matched**	**Unmatched**	**Matched**	**Unmatched**	**Matched**	**Unmatched**
Starting date	**Daily returns**					
1 October 2019	0.00216**** (0.00065)	0.00237**** (0.00064)	0.00183*** (0.00065)	0.00211**** (0.00064)	0.00180*** (0.00064)	0.00209*** (0.00064)
1 November 2019	0.00229*** (0.00072)	0.00249**** (0.00072)	0.00194*** (0.00072)	0.00221*** (0.00072)	0.00191*** (0.00071)	0.00219*** (0.00072)
1 January 2020	0.00328**** (0.00099)	0.00372*** (0.00115)	0.00282*** (0.00099)	0.00336*** (0.00116)	0.00279*** (0.00099)	0.00333*** (0.00116)
1 February 2020	0.00352** (0.00138)	0.00409** (0.00201)	0.00277** (0.00138)	0.00350* (0.00204)	0.00275** (0.00138)	0.00348* (0.00204)

Starting date						
	Weekly returns					
1 October 2019	0.01356**** (0.00315)	0.01449**** (0.00312)	0.01309**** (0.00315)	0.01383**** (0.00313)	0.01298**** (0.00312)	0.01373**** (0.00315)
1 November 2019	0.01456**** (0.00344)	0.01539**** (0.00349)	0.01392**** (0.00344)	0.01451**** (0.00350)	0.01379**** (0.00340)	0.01439**** (0.00350)
1 January 2020	0.02192**** (0.00485)	0.02395**** (0.00545)	0.02063**** (0.00486)	0.02214**** (0.00555)	0.02049**** (0.00478)	0.02203**** (0.00559)
1 February 2020	0.03096**** (0.00720)	0.03401**** (0.01013)	0.02895**** (0.00723)	0.03117*** (0.01045)	0.02871**** (0.00709)	0.03096*** (0.01064)
Starting date	**Volume of trade**					
1 October 2019	−380,809,569 (246,437,207)	−348,974,111 (215,138,007)	−352,056,884 (246,755,570)	−326,134,402 (213,110,893)	−333,539,889 (435,521,234)	−311,617,402 (386,080,782)
1 November 2019	−204,712,197 (267,782,498)	−189,500,480 (240,854,576)	−173,966,614 (268,154,331)	−165,160,148 (238,980,923)	−173,579,920 (477,258,163)	−164,934,376 (423,416,141)
1 January 2020	76,198,394 (316,712,574)	63,963,986 (323,164,871)	117,336,469 (317,276,848)	96,196,642 (321,064,562)	117,000,230 (596,591,867)	95,980,314 (561,624,585)
1 February 2020	−471,686,439 (345,520,868)	−430,941,504 (264,611,126)	−399,116,226 (346,409,382)	−372,289,646 (262,141,308)	−398,778,727 (716,243,767)	−371,962,266 (569,798,887)
Starting date	**Amihud's illiquidity**					
1 October 2019	−0.44694 (2.07759)	−0.68379 (2.00670)	−0.46312 (2.08037)	−0.69527 (2.01692)	−0.46071 (2.07948)	−0.69211 (2.02032)
1 November 2019	−0.93929 (2.33654)	−1.17218 (2.38315)	−0.96161 (2.33989)	−1.18885 (2.39818)	−0.95805 (2.33921)	−1.18470 (2.40269)
1 January 2020	0.98831 (1.34220)	0.76685 (1.05080)	0.98248 (1.34467)	0.76517 (1.04724)	0.98237 (1.34837)	0.76541 (1.04996)
1 February 2020	0.54120 (1.89853)	0.26685 (1.02221)	0.52821 (1.90366)	0.26053 (1.01785)	0.52830 (1.91037)	0.26086 (1.01061)
Starting date	**Range**					
1 October 2019	−0.00122**** (0.00007)	−0.00165**** (0.00008)	−0.00111**** (0.00007)	−0.00157**** (0.00008)	−0.00111**** (0.00008)	−0.00156**** (0.00009)
1 November 2019	−0.00130**** (0.00008)	−0.00171**** (0.00009)	−0.00118**** (0.00008)	−0.00162**** (0.00009)	−0.00118**** (0.00009)	−0.00161**** (0.00009)
1 January 2020	−0.00148**** (0.00010)	−0.00189**** (0.00010)	−0.00133**** (0.00010)	−0.00176**** (0.00010)	−0.00132**** (0.00011)	−0.00175**** (0.00010)
1 February 2020	−0.00186**** (0.00014)	−0.00218**** (0.00013)	−0.00161**** (0.00014)	−0.00196**** (0.00013)	−0.00161**** (0.00015)	−0.00196**** (0.00014)
Starting date	**Weekly volatility**					
1 October 2019	−4,693.8**** (1,108.1)	−5,126.1**** (1,081.1)	−3,603.7*** (1,109.2)	−4,254.2**** (1,096.3)	−3,574.3*** (1,119.9)	−4,205.3**** (1,125.5)
1 November 2019	−5,583.4**** (1,220.1)	−6,077.6**** (1,261.7)	−4,458.8**** (1,221.2)	−5,176.0**** (1,282.9)	−4,465.6**** (1,232.8)	−5,173.1**** (1,322.1)
1 January 2020	−10,638.5**** (1,706.5)	−11,097.0**** (2,223.9)	−9,384.3**** (1,708.1)	−10,096.2**** (2,272.8)	−9,391.1**** (1,725.1)	−10,111.5**** (2,372.4)
1 February 2020	−11,831.3**** (1,843.7)	−12,140.3**** (2,926.4)	−10,156.5**** (1,840.5)	−10,793.2**** (3,000.1)	−10,196.5**** (1,845.8)	−10,843.7**** (3,094.0)

Note: *p < 0.1; **p < 0.05; ***p < 0.01

Table 20. Regression estimates for uptick rule by starting date

Specification:	(1)		(2)		(3)	
Sample:	**Matched**	**Unmatched**	**Matched**	**Unmatched**	**Matched**	**Unmatched**
Starting date	**Daily returns**					
1 October 2019	0.00268**** (0.00057)	0.00312**** (0.00064)	0.00267**** (0.00057)	0.00310**** (0.00064)	0.00264**** (0.00056)	0.00306**** (0.00063)
1 November 2019	0.00250**** (0.00061)	0.00320**** (0.00066)	0.00250**** (0.00061)	0.00319**** (0.00066)	0.00247**** (0.00061)	0.00316**** (0.00065)
1 January 2020	0.00321**** (0.00080)	0.00414**** (0.00078)	0.00324**** (0.00080)	0.00416**** (0.00078)	0.00321**** (0.00080)	0.00413**** (0.00078)
1 February 2020	0.00212** (0.00099)	0.00331**** (0.00097)	0.00218** (0.00099)	0.00335**** (0.00096)	0.00217** (0.00099)	0.00333**** (0.00097)
Starting date	**Weekly volatility**					
1 October 2019	0.00730*** (0.00273)	0.00840*** (0.00302)	0.00671** (0.00272)	0.00754** (0.00302)	0.00660** (0.00269)	0.00742** (0.00301)
1 November 2019	0.00614** (0.00294)	0.00839*** (0.00307)	0.00544* (0.00294)	0.00739** (0.00307)	0.00533* (0.00290)	0.00726** (0.00306)
1 January 2020	0.00731* (0.00389)	0.01018*** (0.00345)	0.00628 (0.00390)	0.00869** (0.00346)	0.00618 (0.00383)	0.00859** (0.00346)
1 February 2020	0.00195 (0.00519)	0.00616 (0.00427)	0.00052 (0.00520)	0.00415 (0.00432)	0.00046 (0.00509)	0.00408 (0.00434)
Starting date	**Volume of trade**					
1 October 2019	−21,421,563 (95,718,062)	−240,259,266 (228,223,444)	−21,369,264 (95,718,567)	−237,233,196 (228,001,543)	−20,344,519 (171,314,547)	−223,717,561 (437,121,793)
1 November 2019	−7,443,165 (102,477,047)	−57,471,538 (249,334,550)	−7,494,501 (102,477,759)	−55,823,501 (249,227,175)	−7,454,973 (185,664,294)	−56,290,260 (469,262,541)
1 January 2020	20,741,859 (115,098,322)	283,957,782 (309,843,716)	20,299,572 (115,101,452)	280,469,810 (309,972,799)	20,273,352 (223,068,377)	279,349,145 (582,357,717)
1 February 2020	10,289,974 (112,364,493)	120,347,834 (303,561,384)	9,277,734 (112,370,457)	112,609,857 (303,587,255)	9,270,874 (242,127,458)	112,079,805 (638,695,247)
Starting date	**Amihud's illiquidity**					
1 October 2019	−0.01011 (0.01740)	−0.09343* (0.05641)	−0.01010 (0.01740)	−0.09273* (0.05606)	−0.01006 (0.01796)	−0.09245 (0.05812)
1 November 2019	−0.01008 (0.01926)	−0.08461 (0.05720)	−0.01009 (0.01926)	−0.08421 (0.05701)	−0.01006 (0.01928)	−0.08402 (0.05931)
1 January 2020	−0.00525 (0.02583)	−0.04410 (0.06380)	−0.00537 (0.02583)	−0.04495 (0.06419)	−0.00535 (0.02716)	−0.04492 (0.06775)
1 February 2020	−0.00824 (0.03054)	−0.08176 (0.06070)	−0.00849 (0.03054)	−0.08349 (0.06149)	−0.00847 (0.03183)	−0.08339 (0.06388)
Starting date	**Range**					
1 October 2019	−0.00178**** (0.00009)	−0.00221**** (0.00008)	−0.00178**** (0.00009)	−0.00220**** (0.00008)	−0.00177**** (0.00009)	−0.00219**** (0.00009)
1 November 2019	−0.00177**** (0.00010)	−0.00219**** (0.00009)	−0.00177**** (0.00010)	−0.00218**** (0.00008)	−0.00177**** (0.00010)	−0.00217**** (0.00009)
1 January 2020	−0.00153**** (0.00012)	−0.00188**** (0.00009)	−0.00155**** (0.00012)	−0.00189**** (0.00009)	−0.00154**** (0.00013)	−0.00188**** (0.00009)

Starting date	Range					
1 February 2020	−0.00119**** (0.00015)	−0.00140**** (0.00011)	−0.00122**** (0.00015)	−0.00142**** (0.00011)	−0.00121**** (0.00016)	−0.00141**** (0.00011)
Starting date	**Weekly volatility**					
1 October 2019	−4,261.9**** (700.2)	−4,216.0**** (744.5)	−4,126.6**** (682.7)	−3,955.0**** (723.9)	−3,939.4**** (705.4)	−3,753.3**** (762.4)
1 November 2019	−4,972.3**** (754.5)	−4,652.9**** (781.4)	−4,923.4**** (734.8)	−4,475.8**** (760.9)	−4,742.5**** (758.0)	−4,286.8**** (802.7)
1 January 2020	−6,512.2**** (970.6)	−6,646.7**** (978.8)	−6,881.7**** (945.0)	−6,890.3**** (958.9)	−6,755.7**** (978.6)	−6,768.9**** (1,017.3)
1 February 2020	−4,851.3**** (1,155.1)	−5,222.4**** (1,194.8)	−5,703.4**** (1,125.0)	−5,976.2**** (1,174.1)	−5,625.3**** (1,166.6)	−5,894.3**** (1,242.6)

Note: *p < 0.1; **p < 0.05; ***p < 0.01; ****p < 0.001.

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Impact of Financial Strategies on Banking Efficiency in Nigeria

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Abstract

This study examines the impact of such financial strategies as income diversification, financial leverage, and liquidity management on the technical efficiency of Nigerian banks between 2010 and 2024. A two-phase methodology was used. In the first phase, efficiency scores were estimated using Data Envelopment Analysis (DEA), applying both raw and bias-corrected measures. In the second phase, Tobit and Simar – Wilson bootstrapped truncated regressions were used to assess the influence of the financial strategies on bank efficiency. This ensures the robustness of results. The findings confirm that liquidity management consistently emerged as the only significant determinant of efficiency across both models. While Tobit results suggested that financial leverage might enhance efficiency, this effect was not supported under the more reliable Simar – Wilson procedure, indicating that leverage is not statistically significant. Income diversification, measured through Trading Income Ratio (TIR) and Fee and Commission Income Ratio (FCIR), was negligible in both models. Overall, the evidence shows that efficiency in Nigerian banks is driven primarily by effective liquidity management, rather than by capital structure or income diversification.

Keywords: financial strategies, banking efficiency, data envelopment analysis (DEA), Simar – Wilson regression, technical efficiency, Nigerian banks

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Introduction

The importance of the banking sector in today's financial systems cannot be overemphasised. It promotes economic growth and investment. It also plays a crucial role in loan advancement and saving money. In many developing nations, such as Nigeria, banks are vital for money circulation, price stability, and development project funding. No wonder both academics and policymakers have developed a keen interest in the technical performance and efficiency of banks. Moreover, due to heightened competition, technological advancements and regulatory changes, Nigerian banks are striving to perform efficiently for sustainability [1].

The ability of a bank to generate the maximum output from its available inputs is measured by technical efficiency, and it has been a crucial tool for evaluating an organisation's performance [2]. Efficient banks can reduce waste, maximise resource use, and offer more value to both their customers and shareholders. However, achieving this degree of efficiency requires more than just traditional financial performance management or internal cost containment. It comprises managing the financial factors that influence operational capacity and resilience in a comprehensive and strategic manner [3].

Three crucial financial strategies: income diversification, liquidity optimisation, and financial leverage are recognised as one of the main factors influencing bank performance. In the literature, a lot has been done in examining each of these three independently, and depending on the context, the findings can be conflicting. Moreover, little is known about the extent of their overall impact on bank efficiency, particularly in the financial markets of sub-Saharan Africa.

When banks are increasingly utilising income diversification strategies, they rely less on traditional interest-based income, which is unpredictable and sensitive to changes in monetary policy. For instance, in the Nigerian banking sector, where currency devaluation, inflation, and changing interest rates are common, banks can utilise non-interest income sources, such as trading, fees, commissions, and other off-balance sheet income, to foster efficiency. Diversification enables risk sharing and the creation of more stable revenues, thereby improving the efficiency of resource use [4].

Liquidity optimisation is another significant pillar of prudent financial strategy. It involves maintaining a balanced level of liquid assets relative to liabilities to avoid insolvency, meet short-term obligations and capitalise on profitable investment opportunities. Efficient liquidity management not only prevents liquidity crises but also ensures depositor and investor confidence. Liquidity limitations will probably impair banks' operational effectiveness in low-income nations like Nigeria, where credit risk is still a major concern and financial markets may be shallow. Thus, optimising liquidity serves a strategic as well as a preventative purpose [5].

Furthermore, the use of financial leverage, which entails taking out loans to finance operations or buy assets, has a more complicated effect on bank efficiency. Leverage can increase returns on equity and make capital expansion easier, which can lead to growth and higher productivity. However, excessive and unmanaged financial leverage increases financial risk and can reduce efficiency, particularly during times of economic downturns and financial distress. In emerging economies like Nigeria, the effect of financial leverage on bank efficiency can be disastrous if not well managed [6].

Despite the fact that there is a wealth of theoretical and empirical knowledge regarding the effect of each of these financial strategies on efficiency, there is comparatively little empirical research on how they jointly impact banks' technical efficiency. In emerging economies, a deeper understanding of bank performance can only be attained by comprehending the interdependence and interactive influence of these financial factors. This is particularly true in Nigeria, where operations are made more challenging by structural economic instability, sporadic regulatory changes and ongoing banking sector reforms [7].

This study, therefore, aims to investigate the combined effects of financial leverage, liquidity optimisation, and income diversification on the technical efficiency of Nigerian banks. It seeks to close a sizable gap in the literature. Through an empirical methodology that employs Data Envelopment Analysis (raw and Bootstrapped) to estimate efficiency scores and Tobit and Simar – Wilson truncated regression models to assess the overall impact of financial strategies. The study seeks to ascertain whether the interplay between these variables improves or degrades operational efficiency. This study offers a new conceptual framework for comprehending the multifaceted factors that influence bank efficiency in developing economies, which is its theoretical and applied contribution.

Literature review

The effects of financial leverage, income diversification, and liquidity management have received considerable scholarly attention in relation to bank efficiency and performance, especially in emerging markets. In the Nigerian context, where the operating environment is characterised by regulatory reforms, macroeconomic volatility, and evolving business models, understanding how these financial strategies interact to influence technical efficiency is essential. The existing literature, however, shows mixed findings and limited integrated analysis, leaving an important gap that this study seeks to address.

Bank Efficiency and Income Diversification

A large body of research has investigated income diversification, which is often measured through non-interest income streams such as fees, commissions, and trading income. Yet, the empirical evidence is mixed. Some studies suggest a **U-shaped relationship**, which indicates that diversification reduces efficiency at the outset but improves stability as banks gain the strength to coordinate different revenues effectively [8]. In contrast, studies from Vietnam

find that diversification improves performance when supported by strong managerial capabilities and governance frameworks [9]. Other research warns that the volatility of non-interest income, particularly trading income, can counterbalance potential gains [10].

In Nigeria, the empirical findings are equally mixed. While commissions and service fees are shown to enhance bank performance, heavy reliance on foreign exchange earnings has been linked to a reduction in efficiency [11]. These contrasting results suggest that not all forms of diversification contribute equally to efficiency. It also means that institutional and market contexts strongly shape outcomes. This stresses the need to review diversification not in isolation but together with other financial strategies.

Financial Leverage and Bank Efficiency

Financial leverage, usually measured through debt-to-equity, is another financial strategy that can be used to attain efficiency. International evidence shows both potential benefits and risks of financial leverage use. For instance, conservative capital positions may reduce insolvency risk but can also constrain risk management effectiveness, as seen in Islamic banks [12]. Similarly, studies across emerging markets show that too much leverage weakens profitability, reinforcing the case for judicious capital structures [13].

Nigerian studies largely echo these patterns. Research indicates that higher leverage is inversely related to profitability and negatively affects earnings per share [14; 15]. Excessive dependence on debt financing has also been found to wear down overall performance [16]. These findings suggest that while leverage can support growth, its efficiency effects are highly sensitive to context, regulatory oversight, and banks' internal risk controls.

Liquidity Management and Bank Efficiency

Liquidity management remains a foundation of bank stability and efficiency, especially in economies exposed to macroeconomic shocks and regulatory tightening. Empirical studies continually link weak liquidity governance with reduced technical efficiency and increased risk [17; 18]. Effective reserve and cash flow management, by contrast, has been shown to enhance profitability in Nigeria [16].

Still, the evidence is not identical. Some studies report that while capital adequacy improves performance, the loan-to-deposit ratio, though positively correlated with efficiency, is not always statistically significant [19]. Others find that most liquidity indicators, apart from foreign claims, tend to improve performance [20]. Overall, these findings show liquidity as an essential but complex determinant of efficiency. It can interact differently with efficiency depending on both macroeconomic pressures and internal management practices.

Literature Gaps and Positioning

Considering the empirical evidence on the three financial strategies, diversification, leverage, and liquidity, two patterns stand out. First, the evidence remains **mixed and reflects the context, with f**indings often contradictory across countries and even within Nigeria. Second, earlier studies examine these strategies **separately and** offer little insight into how they relate to shape efficiency. This study improves the literature by providing a **joint analysis** of income diversification, financial leverage, and liquidity management within a unified framework, using robust DEA and Simar – Wilson approaches [21]. Moreover, by situating the Nigerian experience within broader debates in African and emerging markets, this study highlights how institutional settings and regulatory reforms mediate the efficiency effects of financial strategies. In doing so, the study responds directly to the need for both conceptual integration and contextualised evidence.

Methodology

Research Design

Data Envelopment Analysis (DEA raw and bootstrapped DEA), Tobit Regression Model, and Simar – Wilson truncated regression are the three statistical tools used in this study. A non-parametric linear programming-based tool called Data Envelopment Analysis (DEA) is used in stage 1 to calculate the banks' technical efficiency scores. In stage 2, the Tobit Regression Model is used to ascertain how income diversification, financial leverage and liquidity optimisation affect technical efficiency. The robustness of the research findings is also ensured by using Simar-Wilson truncated regression with bootstrapped DEA scores.

Data Sources and Sample Selection

The secondary data used in this study were obtained from various reliable sources, such as the Central Bank of Nigeria's (CBN) regulatory reports, the Nigerian Exchange Group's (NGX) reports, and the ledgers and account books of the selected banks. Based on the availability of relevant data and information needed for analysis, 11 of the 14 deposit money banks listed on the Nigerian Exchange Group were selected for the study. The banks are: First Bank, Fidelity Bank, Guaranty Trust Bank, First City Monument Bank, Sterling Bank, United Bank for Africa, Union Bank, Access Bank, Zenith Bank, Wema Bank, and IBTC Stanbic Bank.

Stage One: DEA Measurement of Efficiency

The Data Envelopment Analysis (DEA) technique advocated by Sealey and Lindleyis [22] is used in the study. Specifically, the intermediation approach, which views banks as intermediaries that transform deposits and other funding sources into loans and financial products rather than as producers of financial services, is adopted in this study. Therefore, three inputs are used, i.e., deposits, total equity and total assets. In addition, two output variables are used: loans and advances and total income. With these inputs and outputs, a relative indicator of each bank's capacity to transform inputs into desired financial outputs, Technical Efficiency (TE) scores are determined using the DEA method.

Stage Two: Tobit and Simar-Wilson truncated regression

Here, the impact of income diversification, financial leverage and liquidity management on technical efficiency is examined using Tobit and Simar-Wilson regression modelling. The Technical Efficiency (TE) score calculated using DEA in the first phase is the endogenous variable in this instance. Since these scores fall between 0 and 1, the Tobit model and Simar-Wilson truncated regressions are appropriate for the analysis.

Four independent variables are included in the regression. The first and second, the Fee & Commission Income Ratio (FCIR) and the Trading Income Ratio (TIR), both act as proxies for income diversification and show how much a bank depends on non-traditional revenue streams. The third variable, the bank's capacity to manage liquidity and raise capital for lending operations, is measured by the Loan-to-Deposit Ratio (LDR). The fourth variable is a measure of financial leverage that indicates the percentage of funds raised from debt to equity, which is the Debt-to-Equity Ratio (DER).

Definition of Variables

The variables used in the study are presented and described in Table 1.

Table 1. Definition of variables

Variable	Definition	Formula
Technical Efficiency (TE) (Dependent Variable)	Ratio of the bank's output to input	As stipulated in section Stage 1: DEA of this study
Trading Income Ratio (TIR)	A ratio of the bank's Trading Income to the total income generated	$TIR = \frac{\text{Trading Income}}{\text{Total income}}$
Fee & Commission Income Ratio (FCIR)	A ratio of fee and commission income of the bank to total income	$FCIR = \frac{\text{Fee\&Commission Income}}{\text{Total Income}}$
Loan to Deposit Ratio (LDR)	A ratio of loans granted by a bank to the deposits it received from customers	$LDR = \frac{\text{Loan}}{\text{Deposit}}$
Debt to Equity Ratio (DER)	A ratio of a bank's total liabilities to its Shareholders' equity	$DER = \frac{\text{Total Liability}}{\text{Equity}}$

Source: Author's compilation.

Model Equations

Stage 1: DEA

The computational procedure for implementing the DEA approach to technical efficiency involves a linear programming model. The objective is to minimise the inputs for a given level of output, employing VRS assumptions. The mathematical representation of this input-oriented DEA model is as follows:

$$\min_{\theta,\lambda} \theta$$

$$s.t. \; -y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0$$

$$\lambda \geq 0,$$

where θ is a scalar and λ is a N×1 vector of constants. The value of θ will be the technical efficiency score for a particular bank. It will satisfy θ ≤ 1, with a value of 1 indicating a point on the frontier, and hence a technically efficient bank. The value of θ ≤ 1 identifies the amount of any inefficiency that may be present [22].

Stage 2: Regression

The model specification for the regression (Tobit and Simar – Wilson) used in finding the impact of income diversification, financial leverage and liquidity optimisation on technical efficiency is as follows:

$$TE = \alpha + \beta TIR + \beta_2 FCIR + \beta_3 LDR + \beta_4 DER + \varepsilon_i.$$

In the model, TE represents technical efficiency, while α denotes the intercept. The coefficients of the independent variables are represented by β_1, β_2, β_3, and β_4. The Debt-to-Equity Ratio (DER) measures financial leverage, indicating the bank's proportion of debt financing relative to shareholders' equity. Trading Income to Total Income Ratio (TIR) and Fee & Commission Income Ratio (FCIR) capture the bank's income diversification, whereas the Loan to Deposit Ratio (LDR) reflects a bank's liquidity management practices. Finally, $\boldsymbol{\varepsilon_i}$ represents the error term, accounting for unobserved factors that may influence the outcome.

Results and discussion

Descriptive Statistics

Table 2 presents the descriptive statistics of the variables used in the regressions. From the table, it could be observed that banks operate at an average efficiency of roughly 83.5%, with a median of 88%, according to the bias-corrected efficiency scores (DEA_EFF_BE). However, the

Table 2. Descriptive statistics of dependent and independent variables

	DEA_EFF_BE	DEA_RAW	DER	TIR	FCIR	LDR
Mean	0.834970	0.911273	8.886121	0.291758	8.821394	0.634727
Median	0.880000	1.000000	7.280000	0.280000	7.830000	0.620000
Maximum	0.970000	1.000000	191.2100	0.750000	52.84000	1.150000
Minimum	0.350000	0.380000	2.540000	0.090000	2.420000	0.270000
Std. Dev.	0.122428	0.138146	14.64176	0.095617	5.775772	0.167243
Skewness	–1.868092	–1.765184	11.82899	0.964319	4.162635	0.309258
Kurtosis	6.685110	5.842023	147.5440	5.434319	27.89578	2.948870
Jarque-Bera	189.3314	141.2166	14 7487.1	66.31317	4737.630	2.648086
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.266057
Sum	137.7700	150.3600	1466.210	48.14000	1455.530	104.7300
Sum Sq. Dev.	2.458125	3.129833	35 158.53	1.499390	5470.965	4.587113
Observations	165	165	165	165	165	165

Note: DEA_EFF_BE = Bootstrapped DEA efficiency scores; DEA_RAW= Uncorrected DEA efficiency scores. *Source:* Extracts from EVIEWS Analysis.

distribution is noticeably left-skewed, indicating that while many banks perform close to the frontier, a small number lag far behind. The uncorrected DEA model tends to overestimate efficiency, as evidenced by the raw DEA efficiency scores (DEA_RAW), which have a higher mean of 91% and a median of 100%. The necessity of bias correction is further supported by the fact that both efficiency measures have substantial skewness and kurtosis and are not normally distributed.

The debt-to-equity ratio (DER) shows significant evidence of outliers and excessive leverage among a small number of banks. Its mean is 8.89, with a maximum of 191.2. Although its distribution is positively skewed with a few very profitable banks, the trading income ratio (TIR) is generally stable, averaging 29% with only slight fluctuations. Although the average fee and commission income (FCIR) is 8.82, some banks have very high costs, which are illustrated by fat tails and strong skewness. In contrast, the most balanced indicator is the loan-to-deposit ratio (LDR), which averages 63.5% and has a roughly normal distribution with moderate dispersion, indicating that lending practices across banks are generally consistent.

All of these findings point to liquidity management (LDR) as a more stable and normally distributed indicator of banking performance.

Technical Efficiency of the Banks

The raw and bootstrapped bias-corrected DEA efficiency scores of Nigerian banks from 2010 to 2024 are presented in Tables 3 and 4. The significance of DEA bootstrapping in producing more reliable inferences is highlighted by a comparison of the two sets of results, which reveals significant differences between apparent efficiency and bias-adjusted performance.

Raw DEA scores from the sample's early years (2010–2012) indicated that most banks were reasonably efficient; mean scores were above 0.86, and a number of institutions, including Fidelity, FCMB, Stanbic, Sterling, UBA, Wema, and Zenith, seemed completely efficient. However, with mean efficiency scores falling to 0.82 in 2010, 0.78 in 2011, and 0.76 in 2012, the bias-corrected results paint a more cautious picture. Notably, Union Bank continuously performed poorly during this time, with corrected scores as low as 0.35 to 0.45, which was indicative of weak intermediation and the aftereffects of restructuring difficulties. These trends coincided with a period of major stabilisation and reform in Nigeria's banking sector: the establishment of AMCON in 2010 helped absorb toxic assets and restore bank balance sheets, while 2011 emphasised post-crisis clean-up, stronger capitalisation, and governance amid mounting fiscal pressures. By 2012, the CBN advanced structural change with the launch of the Cashless Economy pilot to deepen electronic payments and reduce reliance on cash transactions. Taken together, these findings suggest that although regulatory interventions initially promoted stability, underlying inefficiencies persisted, particularly among weaker institutions.

There was a recovery phase in 2013–2015. With mean scores above 0.91, raw scores recovered during these years, indicating broad technical efficiency in the industry. Ad-

Table 3. DEA efficiency scores (raw) of the banks

	Access	Fidelity	First	FCMB	GTB	Stanbic	Sterling	UBA	Union	Wema	Zenith	Mean Score
2010	0.92	1	0.93	1	0.73	1	1	1	0.38	1	1	0.91
2011	0.75	1	0.82	1	0.83	1	0.93	1	0.43	1	0.85	0.87
2012	0.63	0.78	0.89	1	0.86	1	1	1	0.49	1	0.8	0.86
2013	0.8	0.87	0.89	1	0.94	1	1	0.73	0.73	1	1	0.91
2014	1	1	0.85	1	0.93	0.95	1	0.87	0.73	1	1	0.94
2015	1	1	0.91	1	1	0.83	1	0.83	0.77	1	1	0.94
2016	1	1	1	1	0.9	0.77	1	0.93	1	1	1	0.96
2017	1	0.99	1	1	0.85	0.72	1	0.83	1	1	1	0.94
2018	1	0.89	1	1	0.75	0.67	1	0.74	0.72	1	1	0.89
2019	1	0.82	1	0.92	0.79	1	1	0.83	0.75	1	1	0.92
2020	1	0.87	1	1	0.74	0.76	1	0.81	0.98	1	1	0.92
2021	1	0.9	1	1	0.67	0.9	1	0.87	1	1	1	0.94
2022	1	0.86	1	1	0.56	0.99	1	0.68	1	1	1	0.92
2023	1	0.97	0.76	1	0.57	1	1	0.56	0.94	1	1	0.89
2024	0.86	0.69	1	1	0.39	1	1	0.51	1	1	1	0.86

Source: Extracts from DEA in R.

ditionally, bias-corrected scores increased, rising from 0.84 to 0.88, reflecting real, albeit smaller, efficiency gains. While mid-tier banks like UBA and Union displayed slow but partial convergence, larger banks such as Zenith, GTB, and Access maintained continuously high corrected efficiency. This phase can be understood as a time of scale expansion and strengthened intermediation, supported by sector-wide reforms. During this period, Nigeria's banking sector deepened digital transformation through the nationwide rollout of the cashless policy and the introduction of the Bank Verification Number (BVN) system, which enhanced KYC processes and fraud prevention. However, these efficiency improvements occurred against the backdrop of declining oil revenues, mounting FX pressures, and political uncertainties, which heightened liquidity risks, triggered monetary tightening, and intensified regulatory scrutiny of banks' stability.

In 2016–2017, efficiency performance peaked. With sectoral averages of 0.96 and 0.94, raw scores reached their highest levels, and almost all banks achieved near-perfect technical efficiency. The bias-corrected results confirm this as the best performance period, with a mean efficiency of 0.96 in 2016 and 0.94 in 2017. Even historically underperforming banks such as Fidelity, Wema, and Union closed efficiency gaps, reflecting stronger intermediation, better use of resources, and the consolidation of earlier reforms. These improvements unfolded in a challenging macroeconomic environment. The sharp depreciation of the naira following the CBN's shift toward a more market-driven exchange rate exposed banks to significant FX risks, prompting stricter provisioning. The subsequent recovery period was marked by continued volatility, reinforced capital and governance requirements, and heightened regulatory focus on AML/CFT compliance, fintech oversight, and the rapid expansion of electronic payments. Together, these dynamics pushed banks to adapt operationally while strengthening efficiency levels across the sector.

The industry saw a slow decline from 2018 to 2020 before stabilising. Bias-corrected scores fell more sharply, dropping to 0.80 in 2018 and 0.85 in 2019, while raw scores declined to 0.89 and 0.92, respectively. These updated findings reveal vulnerabilities that the raw DEA concealed, particularly for GTB and Stanbic, which experienced significant efficiency losses. Efficiency stabilised at 0.86 by 2020, suggesting that banks had partially adapted to market and regulatory pressures, likely linked to tightening credit requirements and persistent exchange rate volatility. This performance coincided with an evolving macroeconomic and regulatory landscape: between 2018 and 2020, the sector underwent ongoing reforms in risk management and corporate governance while rapidly expanding mobile and agent banking. Although non-performing loan

Table 4. DEA Efficiency Scores (Bootstrapped Bias Corrected) of the Banks

	Access	Fidelity	First	FCMB	GTB	Stanbic	Sterling	UBA	Union	Wema	Zenith	Mean Score
2010	0.87	0.92	0.88	0.88	0.68	0.92	0.93	0.89	0.35	0.86	0.88	0.82
2011	0.69	0.85	0.75	0.85	0.77	0.9	0.84	0.88	0.39	0.85	0.78	0.78
2012	0.57	0.73	0.82	0.85	0.79	0.87	0.85	0.84	0.45	0.85	0.73	0.76
2013	0.75	0.82	0.86	0.9	0.88	0.91	0.9	0.69	0.69	0.9	0.89	0.84
2014	0.93	0.95	0.82	0.93	0.9	0.91	0.95	0.83	0.7	0.92	0.94	0.89
2015	0.96	0.92	0.87	0.92	0.93	0.79	0.93	0.8	0.73	0.93	0.92	0.88
2016	0.97	0.95	0.97	0.95	0.87	0.74	0.96	0.9	0.94	0.94	0.94	0.92
2017	0.95	0.94	0.93	0.92	0.81	0.68	0.92	0.79	0.93	0.92	0.92	0.88
2018	0.88	0.84	0.87	0.88	0.7	0.63	0.88	0.69	0.68	0.88	0.88	0.80
2019	0.9	0.78	0.91	0.86	0.75	0.91	0.94	0.78	0.71	0.91	0.91	0.85
2020	0.91	0.83	0.91	0.95	0.71	0.73	0.93	0.78	0.92	0.91	0.92	0.86
2021	0.92	0.86	0.92	0.93	0.64	0.88	0.93	0.83	0.91	0.92	0.93	0.88
2022	0.88	0.8	0.89	0.88	0.53	0.94	0.93	0.63	0.93	0.87	0.91	0.84
2023	0.86	0.9	0.7	0.87	0.53	0.88	0.85	0.52	0.86	0.86	0.87	0.79
2024	0.74	0.61	0.85	0.85	0.35	0.89	0.84	0.45	0.86	0.82	0.81	0.73

Source: Extracts from DEA with Bootstrap in R.

metrics improved, macroeconomic fragilities persisted. The COVID-19 shock in 2020 further disrupted the system, compelling the CBN to deploy wide-ranging interventions that reshaped banks' credit flows, asset quality practices, and liquidity support to households and businesses.

The years 2021–2022 demonstrate resiliency in the face of COVID-19 aftershocks and other macroeconomic pressures. While bias-corrected averages remained comparatively strong at 0.88 and 0.84, raw scores held steady at 0.94 and 0.92. Notably, Union Bank significantly improved during this time, reducing its long-standing efficiency gap with peers and achieving corrected scores of 0.91 and 0.93. In contrast, GTB's corrected efficiency dropped sharply to 0.53 in 2022, signalling a weakening of intermediation capacity. These dynamics unfolded within a shifting macro-financial environment. In 2021, the launch of the eNaira positioned banks within a new digital currency and payment framework, intersecting with pandemic recovery and evolving global financial conditions. By 2022, the CBN's currency redesign disrupted cash circulation, creating liquidity pressures, operational challenges, and shifts in deposit mobilisation. Together, these developments shaped banks' efficiency outcomes, reinforcing resilience for some institutions while exposing fragilities in others.

The 2023–2024 results show a renewed sectoral decline. Bias-corrected scores reveal deeper inefficiencies, with averages falling to 0.79 in 2023 and 0.73 in 2024, while raw scores dropped to 0.89 and 0.86, respectively. This downturn was widespread, but the weakest performances came from GTB, which fell to 0.35 in 2024, and UBA, which dropped to 0.45, both signalling severe stress in intermediation efficiency. These outcomes suggest that the industry is grappling with deteriorating asset quality, rising funding costs, and unstable macroeconomic conditions. The decline coincided with major policy and market shifts: in 2023, the unification of exchange rates and sharp naira devaluation reshaped banks' FX positions, while leadership changes at the CBN redirected regulatory priorities. By 2024, banks faced heightened inflation, escalating credit risks, and balance sheet repricing, even as ongoing reforms sought to strengthen monetary policy credibility and enhance payment oversight. Collectively, these dynamics intensified efficiency challenges across the sector.

When combined, the analysis shows that while bias-corrected results offer a more cautious and accurate assessment, raw DEA scores consistently overstate efficiency. According to the data, Nigerian banks' efficiency peaked between 2016 and 2017, then declined sharply in the following years before remaining relatively resilient through 2021 and 2022. Crucially, the findings highlight how long-term sustainability is still threatened by enduring structural issues, even though reforms and intermediation gains momentarily increased efficiency.

Table 5. Correlation of variables

	DEA_EFF_BE	DEA_RAW	TIR	FCIR	DER	LDR
DEA_EFF_BE	1.000000	0.964429	–0.220407	–0.073070	0.036815	0.536945
DEA_RAW	0.964429	1.000000	–0.199266	–0.052643	0.096114	0.466135
TIR	–0.220407	–0.199266	1.000000	0.025761	–0.108262	–0.264310
FCIR	–0.073070	-0.052643	0.025761	1.000000	–0.018965	–0.101755
DER	0.036815	0.096114	–0.108262	–0.018965	1.000000	–0.169876
LDR	0.536945	0.466135	–0.264310	–0.101755	–0.169876	1.000000

Source: Extracts from EVIEWS Analysis.

Stage 2. Impact of Income Diversification, Financial Leverage and Liquidity Optimisation on the Technical Efficiency of Banks

Multicollinearity and heteroscedasticity tests were performed to validate the models' assumptions. The Breusch – Pagan – Godfrey test, a key diagnostic for heteroscedasticity, indicated that the models do not suffer from heteroscedasticity, as the null hypothesis of homoscedasticity could not be rejected. Additionally, the Pearson correlation matrix revealed no evidence of autocorrelation or cross-sectional dependence. Furthermore, the Wald test statistic rejected the null hypothesis that the regression parameters are jointly equal to zero, confirming the overall significance of the models.

Correlation of Variables

In Table 5, the reliability of efficiency measurement is confirmed by the correlation results, which demonstrate a strong and positive relationship between the bias-corrected and raw DEA efficiency scores (r = 0.964). The loan-to-deposit ratio and efficiency have a moderately positive correlation (DEA_EFF_BE: r = 0.537; DEA_RAW: r = 0.466), suggesting that the technically more efficient banks are typically those with greater intermediation capacity. Reliance on trading income and fee and commission income, on the other hand, may not improve efficiency and may reflect revenue concentration risks, as both efficiency measures show a negative correlation with the trading income ratio (DEA_EFF_BE: r = –0.220; DEA_RAW: r = –0.199) and fee and commission income ratio (DEA_EFF_BE:

Table 6. Estimation results of the Tobit Regression model

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.080899	0.147326	0.549117	0.5829
TIR	0.208175	0.200970	1.035854	0.3003
FCIR	–0.001999	0.002893	-0.691013	0.4896
DER	0.045185	0.008077	5.594292	0.0000
LDR	0.861117	0.123458	6.974965	0.0000
Error Distribution				
SCALE:C(6)	0.192684	0.018225	10.57261	0.0000
Mean dependent var	0.911273	S.D. dependent var		0.138146
S.E. of regression	0.098109	Akaike info criterion		0.514917
Sum squared resid	1.530424	Schwarz criterion		0.627860
Log likelihood	–36.48062	Hannan-Quinn criter.		0.560764
Avg. log likelihood	–0.221095			
Left censored obs	0	Right censored obs		95
Uncensored obs	70	Total obs		165

Source: Extracts from EVIEWS Analysis.

r = –0.073; DEA_RAW: r = –0.053). It is implied that changes in trading, fee and commission income and leverage have little direct impact on technical efficiency because the trading income ratio, the fee and commission income ratio and the debt-to-equity ratio exhibit very weak correlations with efficiency.

All of these results highlight the fact that efficient loan-deposit intermediation, not income diversification or capital structure modifications, is the main means through which Nigerian banks attain efficiency.

Tobit Regression

The Tobit regression results (Table 6) shed light on the factors influencing bank efficiency in Nigeria. According to the model, the most significant predictors of efficiency are the debt-to-equity ratio ($\beta = 0.045$, $p < 0.001$) and the loan-to-deposit ratio ($\beta = 0.861$, $p < 0.001$). These results imply that banks attain greater efficiency levels when they strategically use leverage and convert deposits into loans more successfully. However, the coefficients for the trading income ratio and fee and commission income ratio are statistically insignificant, suggesting that income diversification has less of an impact on efficiency in the current sample.

Many banks are already at the efficiency frontier, as evidenced by the high percentage of right-censored observations (57.6%), with capital structure and intermediation capacity accounting for the majority of variances. Overall, the findings demonstrate how crucial liquidity and leverage strategies are in determining bank efficiency in Nigeria's banking industry.

Table 7. Simar – Wilson truncated regression

Variable	Coefficient	Std. Error	z-stat	p-value	Significance
TIR	0.00086	0.01266	0.07	0.946	Not sig.
FCIR	0.00228	0.00469	0.49	0.627	Not sig.
DER	0.03935	0.60100	0.07	0.948	Not sig.
LDR	0.81702	0.26985	**3.03**	**0.002**	Significant at 1%

Source: Extracts from FEAR 4.0 in R Analysis (21).

Simar – Wilson Bootstrapped truncated regression

The Loan-to-Deposit Ratio is the sole statistically significant factor influencing bank efficiency in Nigeria, according to the findings of the Simar – Wilson bootstrapped truncated regression (Table 7). Improvements in intermediation capacity significantly increase efficiency, as evidenced by the large and positive estimated coefficient of LDR ($\beta = 0.817$, SE = 0.270, $z = 3.03$, $p < 0.01$). In contrast, the debt-to-equity ratio, fee and commission income ratio, and trading income ratio all show positive but statistically insignificant coefficients, indicating that leverage and diversification have little bearing on efficiency during the sample period. Significant residual heterogeneity across banks is indicated by the estimated error variance ($\sigma = 0.719$), suggesting that efficiency may also be influenced by unobserved institutional or market-level factors.

When combined, these results demonstrate how important efficient liquidity management is in determining the technical efficiency of Nigerian banks, whereas financial leverage and income diversification have relatively minor impacts.

Table 8. Tobit versus Simar – Wilson truncated regressions results

Variable	Tobit Coef. (z-stat, p-value)	Simar – Wilson Coef. (z-stat, p-value)	Comparison
TIR (Trading Income Ratio)	0.208 (z = 1.04, p = 0.300)	0.00086 (z = 0.07, p = 0.946)	Positive but insignificant in both models.
FCIR (Fee & Commission Income Ratio)	–0.0020 (z = –0.69, p = 0.490)	0.00228 (z = 0.49, p = 0.627)	Opposite sign, but insignificant in both.
DER (Debt-to-Equity Ratio)	0.0452 (z = 5.59, p < 0.001)	0.0394 (z = 0.07, p = 0.948)	Significant in Tobit, but **not significant** in Simar–Wilson.
LDR (Loan-to-Deposit Ratio)	0.861 (z = 6.97, p < 0.001)	0.817 (z = 3.03, p = 0.002)	Strongly significant in **both** models.

Source: Extracts from EVIEWS and FEAR 4.0 in R Analysis.

Tobit Versus Simar-Wilson Regressions

Important information about the robustness of the model is obtained by comparing the Tobit and Simar – Wilson regressions. Because efficiency scores are bounded and subject to censoring, this dual approach offers a robustness check. While the trading income ratio (TIR) and fee and commission income ratio (FCIR) were statistically insignificant, the loan-to-deposit ratio (LDR) and debt-to-equity ratio (DER) had statistically significant and positive effects on efficiency, according to the Tobit regression results. LDR showed the biggest impact among these, indicating that banks with more intermediation capacity, those that turn a larger percentage of deposits into loans, tend to be substantially more efficient. According to the Tobit specification, DER also seemed to increase efficiency, suggesting that financial leverage could facilitate resource use and efficiency.

However, the significance of DER vanished after Simar – Wilson bootstrapping was used to account for the bias and serial correlation present in DEA efficiency scores. The only ratio that was still positive and statistically significant was LDR. This discrepancy raises the possibility that distributional assumptions and uncorrected bias caused Tobit estimates to overestimate the importance of leverage. The bootstrapped truncated regression, on the other hand, offers a more cautious and reliable conclusion, demonstrating that intermediation capacity (loan to deposit ratio) is a strong and predominant factor influencing efficiency in Nigerian banks.

Another notable fact is that TIR and FCIR are consistently insignificant in both models. The results indicate that trading, fee-based, and commission income are still too underdeveloped in the Nigerian context to have a significant impact on efficiency, despite the fact that theory frequently highlights income diversification as a stabilising factor for banks.

Conclusion

This study examined the impact of income diversification, financial leverage, and liquidity management on the technical efficiency of Nigerian banks. Efficiency scores were first estimated using Data Envelopment Analysis (DEA) in both raw and bootstrapped forms. In the second stage, Tobit and Simar–Wilson regressions were employed to investigate the impact of financial leverage, income diversification and liquidity management on the technical efficiency of Nigerian banks. This two-step approach ensured the reliability of the findings and provided deeper insights into the determinants of banking efficiency over the study period.

This study shows that liquidity management, especially the Loan-to-Deposit Ratio (LDR), is the most consistent driver of banking efficiency in Nigeria. The roles of income diversification and leverage remain weak under robust bias-corrected methods. The DEA results, validated by Simar–Wilson regressions, revealed that although banks achieved periods of strong efficiency, peaking in 2016, sustained performance depended largely on effective credit intermediation. Therefore, a key policy implication rooted in the findings of this study is that banks should strengthen liquidity practices by meeting LDR benchmarks alongside Basel III standards such as the Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR). A balanced debt-to-equity ratio of about 2:1 to 3:1 is also recommended to avoid excessive leverage while supporting intermediation. The Central Bank of Nigeria can enhance efficiency through refined LDR policies and risk-based supervision. In addition, CBN can support long-term funding markets, while banks themselves should diversify funding sources beyond short-term deposits. Collectively, these measures would consolidate efficiency gains and improve the sector's resilience to macro-financial shocks.

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Internal and External Determinants of Credit Risk: Empirical Evidence from Iraqi Commercial Banks

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Abstract

Credit risk determinants are highly relevant because prolonged high credit risk can damage the reputation of banks and erode customer confidence. This paper therefore investigates the internal (bank-specific), external (macroeconomic and government-level) determinants of credit risk in Iraq. The model is estimated using unbalanced panel data of 18 conventional banks over the 2005–2024 period by employing the Pooled OLS (POLS) method. Liquidity decreases credit risk, whilst capital adequacy and bank size increase it as banks are more likely to engage in risky lending activities due to inefficiency in the loan approval process or else because of their huge size. In addition, macroeconomic determinants such as GDP, inflation, and political unrest have negative effects on credit risk, which in turn results in a low quality of loan portfolios. Strict capital regulations may even lead to risk-taking behaviour in the banking industry in order to mitigate their compliance costs. High bank profits may also conceal the increasing credit risk in the banks. The banks with stronger regulatory compliance have lower defaults and higher stability. Finally, the findings emphasize the need for appropriate banking policies and practices in Iraq, which would be flexible enough to address the country-specific conditions and which would include management of liquidity and capital cushion. In addition, addressing structural economic and political challenges is needed to restore stability and sustainable development of the banking sector, especially in developing fragile economies. Furthermore, using alternative risk measures and alternative time-periods, we also find robustness in our results. However, the analysis only covers commercial banks, and, due to data limitations, during the conflict years. Future research can utilize banks, including Islamic and private banks, and explore possible nonlinear effects of capital regulation.

Keywords: credit risk, panel data analysis, bank-specific, economic variables, government variables

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Introduction

The 2008 global financial crisis fundamentally reshaped scholarly and regulatory discourse on credit risk, particularly within developing economies. Non-performing loans (NPLs) have recently moved to the foreground as a factor that affects the performance and assets of banks. Banks function on a hairpin of confidence, and most of their liabilities consist of deposits (over 85% on average) [1]. Thus, they are extremely sensitive and become weakened even by a slight loss of trust by their depositors. NPLs require additional loan loss provisions that reduce banks' net income and constrain their lending capabilities. Assets and liabilities of banks have different maturities, which expose them to liquidity risk and cause a decrease in their credit rating and loss of their reputational capital. This factor affects banks operating in developing countries most, as these countries have underdeveloped institutions, unpredictable economic conditions, and uneven regulatory enforcement [2].

Empirical studies conducted so far have produced mixed results as to the determinants of the credit risk both from internal (bank-specific) and external (macroeconomic) perspectives. For the developing economies, credit risk analysis is critical to policy makers and managers in the industry. In a study conducted by Yagli and Topcu [3] on the performance of banks in Turkey between 2013 and 2018, the authors concluded that both internal bank-specific factors as well as external macroeconomic variables affect credit risk. The extent to which these factors affect credit risk, however, depends greatly on the ownership structure in the industry. According to the study, managing credit risk in financial industry may not be possible through a single legislation. Hence, a single legislation may not be sufficient for managing credit risk in the financial industry.

Researchers, policymakers, and banking professionals alike are curious to understand the key internal and external factors that can impact the credit risk of a customer. It is common knowledge that commercial banks form the backbone of financial systems around the world and are exposed to great risk of credit. Both internal and external factors can play a large role in the overall credit risk that a bank faces [4]. These factors are particularly important in post-conflict economies, such as Iraq, which has a fragile institutional structure and heavily relies on the single-source oil sector to drive its economy. New risks and ways of managing risk have emerged that require innovative and customized solutions not previously encountered [5; 6].

Studies also indicate that within a bank, the capacity to control credit risks is largely a function of the bank's internal management factors, such as its manager's effectiveness, asset quality, capital and operating efficiency. A bank with high operating efficiency and profitability is less exposed to credit shocks than its lower performing peers in emerging markets [7]. However, external factors that significantly impact loan issuance policies include macroeconomic performance, the competitive landscape, and the efficiency of the legal and regulatory system. Information asymmetry and credit risk are made worse in the case of Iraq by monetary and fiscal policy instability, poor corporate governance, and an inadequate accounting system that shows up as differences in the application of International Financial Reporting Standards (IFRS) [8]. Iraqi banks handle their loan portfolios in a unique way due to the intricate interaction of internal and external factors.

Every organization is particularly concerned with the cost of taking on risk. During the reviewed period, company stocks faced a number of uncertainties and problems related to its business activities. Many corporations faced extremely difficult circumstances during that extraordinary period, and Iraq in particular endured more instability during that time [9]. Credit risk is one of the main causes of Iraqi banks' instability. They also assess the sustainability of individual banks against that of banks around the world, and in every case have found them to be more sustainable. Furthermore, there are relatively few studies examining the procyclicality of credit risk [10]. Given the restrictions indicated above, the purpose of this work is to fill the gap in the literature by:

1) Concentrating on the traditional banks doing business in Iraq.
2) Developing fresh empirical data from the standpoint of national governance dimensions.

Thus, understanding the nature of the relationship between these elements and how they affect credit risk is crucial for creating sound banking policies and is not just an academic issue. Iraqi banks can improve their financial resilience and support the stability of the financial system and the nation's economic growth by specifically recognizing these elements.

The rest of the paper is structured as follows. The hypotheses of this research are developed and the literature is reviewed in second section. Data and the econometric model are introduced in third section. The empirical results of the panel data analysis are covered in fourth section. The paper is concluded in fifth section, which also identifies its shortcomings and offers recommendations for further study.

Literature review and hypothesis development

The Resource-Based View (RBV) was used to write the credit risk literature over thirty years ago. The RBV theory asserts that for an organization to improve its financial performance and obtain a competitive advantage, its resources and capabilities must be managed strategically. The RBV Theory provides a rationale for the assertion that managerial and resource management competencies possess the capacity to enhance credit market share, service diversification, and operational efficiency within banks. As a result, these competencies may aid in acquiring a competitive edge within the financial sector. This research focuses on examining how these factors influence the credit risk that banking, a critical operation in the financial sector, may face.

Numerous studies of the variables influencing credit risk in both developed and emerging economies have been carried out in recent decades. However, no research has been conducted to investigate the factors that influence credit risk in Iraq. The literature will take into account various aspects of factors that affect credit risk, which include government variables, economic indicators, and bank-specific characteristics. The liquidity ratio, leverage, capital adequacy ratio, return on assets, and bank size are all factors that are unique to a given bank and are associated with credit risk. The same researchers contend that economic indicators (such as GDP growth, inflation, and unemployment rates) and government variables (such as government effectiveness, regulatory quality, political instability) are the key external determinants affecting credit risk.

After reviewing the literature, it was feasible to pinpoint the weaknesses of the previous empirical research as well as the gaps in this investigation.

Bank-specific characteristics

Numerous investigations have been carried out using data from various countries. Liquidity ratio, leverage, capital adequacy ratio, return on assets, and bank size are the characteristics related to credit risk. Previous empirical investigations have produced inconclusive results regarding the internal and external factors influencing credit risk. In the context of economies in developing nations, credit risk analysis is vital for policy formulation and management decision-making [10]. Yagli and Topcu [3] examined the Turkish banking sector from 2013 to 2018. The researchers discovered that both internal bank-specific characteristics and external macroeconomic indicators determine credit risk. Nevertheless, the degree to which this impact is felt is substantially contingent upon the ownership framework. Credit risk management in the financial industry may not always be amenable to a single piece of legislation, according to the findings of this research. This research suggests that a single regulation may not always be suitable for addressing credit risk management in the financial industry.

Liquidity is measured by the ratio of liquid assets to total assets, and the variable's intended sign is positive. Managers are encouraged to expand lending when bank liquidity is strong in order to meet the anticipated rate of return. As a result, in such circumstances, banks may see a decline in their credit criteria, which would increase their risk [11]. The ratio of total loans to total deposits is used to calculate funding. By calculating the amount of money the bank uses for loans from the deposits it has collected, this ratio shows how liquid the bank is. The transfer of risk through the internal capital market should be more obvious in banks that are less reliant on deposits since they are more focused on alternative external funding sources. Therefore, the expected sign of the variable is positive, as in [12]. In previous studies, all the influence, positive or adverse, of bank liquidity on the bank's credit risk was recorded. In light of the study prepared by [13], liquidity positively impacts the credit risk of its subsidiaries.

However, Berger and Bouwman [14] examined the association between liquidity and credit risk by utilising a sample of US banks from 1984 to 2011, and they demonstrated that liquidity creation reduces bank risk through enhanced diversification and funding stability. Their findings confirm that liquidity creation reduces bank risk (negative relationship), especially for small banks. Liquidity transformation in excess of needed liquidity creation for customers decreases insolvency risk by 15–20% in times of crises, thus raising stability without increasing fragility. Along these lines, Diamond and Rajan [15] established a theoretical model of banking stability. They found that banks with strong liquidity positions have lower financial fragility since they are able to ward off bank runs of destructive proportion. Thus, optimal banking regulation needs to balance effective requirements for liquidity creation with efficiency objectives. Thus, the liquidity hypothesis as follows:

H1: *Liquidity has a significant negative impact on credit risk.*

Financial leverage of major companies in an industry over several years is the portion of the value of a company's resources. At the business level, financial leverage increases industry income rates. Greater financial leverage, however, carries more serious risks for the company, above all the credit risk [16].

Financing a business with leveraged loans would therefore generate higher costs than conventional financing offered by commercial banks, which consider highly leveraged debt to pose a higher risk of default [17]. Highly leveraged corporations are viewed by creditors as riskier and thus result in higher interest rates for the corporation or in stricter terms and conditions for the financing. Excessive leverage reduces a corporation's credit-worthiness and consequently its credit rating and default probability [18; 19]. While high levels of leverage can provide greater returns during periods of stable economic growth, the corporation can experience greater financial loss during times of economic decline. Thus, high levels of leverage are viewed negatively by financial models and increase a corporation's credit risk. In Malaysia, for example, the effects of the microfinance components on the commercial banking business over the years 1998–2017 were empirically investigated by Yusuf et al. [20] using Asian data. Empirical results showed a positive correlation between credit risk and leverage. For Canada and Mexico, Fischer et al. [21] reported a substantial positive correlation between leverage and bank credit risk. Utilizing a sample of 35 Indonesian banks, Dewi [22] by conducting a study in Indonesia by utilizing a sample 35 banks reported a significant positive effect of leverage on credit risk. Therefore, the following hypothesis H2 can be stated:

H2: *Credit risk is positively and significantly influenced by leverage.*

Banks that are well-capitalized are more resilient as they have a greater capital buffer to absorb losses resulting from credit risk shocks [23]. Furthermore, Ghosh [24] investigated the role of Capital Adequacy Ratio (CAR) in manag-

ing credit risk (measured by non-performing loans, NPLs) in US commercial banks. Using panel data regression analysis for the period 1992q4–2016q1, they found that banks with higher CAR exhibited significantly lower NPLs. Likewise, Kharabsheh [25] analyzed the relationship between CAR and credit risk in Jordanian banks from 2000 to 2017 using dynamic panel models (GMM). The study reported a strong negative relationship. In the same vein, Naili and Lahrichi [26] examined the influence of the capital adequacy ratio on credit risk across Middle East and North African (MENA) emerging markets banks using data from 53 banks listed between 2000 and 2019. The findings confirmed that higher CAR reduced credit risk. Nevertheless, Dirs and Abdullah [23] found an insignificant association between the capital adequacy ratio and credit of 5 Iraqi banks for the period 2018–2022. In order to confirm or to reject the previous inconsistent results the following hypothesis is formulated.

H3: *High Capital Adequacy Ratio leads to low credit risk.*

Khan et al. [27] studied mainly the internal factors of the commercial banking industry of Pakistan over the period from 2005 to 2017. They used panel data regression to obtain the results. The study found a negative correlation between bank performance and non-performing loans (NPL). Moreover, Naili and Lahrichi [26] examined the influence of the capital adequacy ratio on credit risk across Middle East and North African (MENA) emerging markets banks using data from 53 banks listed between 2000 and 2019. This study confirms the earlier finding that higher CAR reduces credit risk. Yusuf et al. [20] in their study examined the impact of microfinance components on commercial banking in Malaysia over the period of 1998 to 2017. The study mainly used empirical data from Asia. According to his research, a direct correlation exists between credit risk and profitability. However, by utilizing a sample of 35 banks from Indonesia, Dewi [22] found that profitability had a significant positive influence on non-performing loans (NPL). Thus, it is hypothesised that:

H4: *Profitability has a significant negative impact on credit risk.*

Many experts believe that larger banks are less likely to have high credit risk, and that there should be a positive relationship between bank size and credit risk [27]. However, [3; 21; 27–30] they had claimed that bank size and credit risk are negatively correlated. Furthermore, Salas and Saurina [29] discovered an adverse association between bank size and non-performing loans, also corroborating the findings. They make it clear that the larger a bank under consideration, the more expansive it will grow over time, which will promote the reduction of credit risk that is mediated by non-performing loans. However, Handajani et al. [30] found an insignificant impact of bank size on credit risk by utilizing a sample of 32 listed Indonesian Banks for the period 2019 to 2021. Hence;

H5: *There is a substantial inverse association between bank size and credit risk.*

Macro-economic variables

Economic indicators that are outside a bank's control and have an impact on credit risk are known as external factors. One of the most important macroeconomic metrics, GDP growth or economic expansion, may have an impact on credit risk. Mpofu and Nikolaidou [31] examined the many factors that influence credit risk in Sub-Saharan Africa and found that an increase in the GDP growth rate has a negative impact on credit risk. Similarly, Castro [32] uses dynamic GMM analysis to examine the macroeconomic factors that influence credit risk for Greece, Ireland, Portugal, Spain, and Italy and finds that reduced credit risk is correlated with higher GDP growth. Similarly, studies in Sub-Saharan Africa that looked at the impact of several macroeconomic factors on CR found that an increase in the GDP growth rate has a negative impact on banks' non-performing loan ratio. Additionally, there was an adverse and significant correlation between GDP and credit risk [33]. Moreover, Škrabić et al. [13] examined the effects of the domestic economic climate and parent bank status on the credit risk of foreign banks in Central and Eastern European (CEE) nations using a sample of banks in these countries. They discovered that the credit risk of a parent bank's subsidiaries is adversely impacted by its GDP growth.

In the same vein, from 1985 to 1997, Salas and Saurina [29] conducted a study by utilizing a sample of Spanish banks using GMM estimate approaches. According to their research, the amount of non-performing loans (NPLs) decreases when economic growth (GDP) increases. Similarly, Fofack [34] looked into the factors that influence credit risk in sub-Saharan nations. He used the Granger causality Test to examine an unbalanced panel data set of 16 sub-Saharan African nations between 1993 and 2003. He found a strong correlation between credit risk and economic growth. However, he contended that this is due to the fact that certain African economies are not diversified. In another research conducted in 1995-2008, Espinoza and Prasad [35] investigated the macroeconomic factors that influence credit risk in 80 banks from the Gulf Cooperation Council countries. They used fixed effects, various GMM, and system GMM models to analyze the banks' panel data set. According to their analysis, credit risk has been significantly impacted by macroeconomic factors like GDP growth. In particular, they showed that credit risk was substantially inversely correlated with economic growth. Hence, the next hypothesis is as follows:

H6: *GDPG had a significantly negative relationship with credit risk.*

The change in the percentage of the price level over the previous period is reflected in the inflation rate. According to Colander [36], the price level is a common tool for measuring inflation because it is an index of all prices in the economy. Additionally, the Consumer Price Index (CPI) calculates set basket prices for consumer items based on the percentage of each component in average consumer spending. Inflation has also been shown to raise credit risk in the literature. Research has shown that an increase in the

rate of inflation has a positive and significant effect on the amount of non-performing loans (NPLs) [31]. Additionally, it was discovered that while variable growth rates reduce banks' credit risk over time, inflation rates raise it. Furthermore, it was noted that market characteristics as well as short- and long-term factors including construction activity, unemployment, and domestic lending rate have an impact on the amount of CR that banks undertake [36; 37]. Likewise, Kharabsheh [25] conducted a study by utilising a sample of Jordanian commercial banks from 2000 to 2017, employing dynamic panel data models, and he found that inflation is significantly positively associated with credit risk in the Jordanian banking sector. Hence,

H7: *Inflation has a significant positive influence on credit risk.*

Bai [38] states that the the share of non-performing loan (NPL) in the banking industry is significantly positively affected by macroeconomic instability, for instance by an increase in unemployment. This is because unemployed people have less ability to repay their loans, which therefore leads to loan defaults. This is the cyclical view of the economy, business cycles affect the credit quality of credit, i.e., during economic recessions the credit quality is declining. This can have negative effects on bank stability and therefore needs to be managed proactively. Nikolaidou and Vogiazas [39] examine unemployment as a macroeconomic factor of credit risk in the Bulgarian banking sector. Their findings are in line with economic theories and most of the other empirical research that links an increase in unemployment with a decrease in a borrower's ability to repay a loan. According to a study by Messai and Jouini [37], which used a sample of 85 banks from three countries (Italy, Greece, and Spain) over the years 2004–2008, unemployment rates had a significantly positive connection with credit risk as measured by NPL. Similarly, Makri et al. [12] examined the macroeconomic and bank-specific factors that influence credit risk in 14 Eurozone nations and discovered a strong positive correlation between credit risk and the unemployment rate. According to Castro [32], who uses dynamic GMM analysis to examine the macroeconomic factors influencing credit risk for Greece, Ireland, Italy, Portugal, and Spain, a decline in the unemployment rate lowers credit risk.

H8: *Unemployment significantly positively affects credit risk.*

Government variables

Strong financial regulation mitigates credit risk by ensuring transparency and reducing moral hazard. Weak regulatory frameworks, however, may encourage excessive risk-taking by financial institutions [40]. Several studies attest to the negative relationship between regulatory quality and NPLs, Barth et al. [40] conducted a cross-country analysis of banking sector regulations and their impact on financial stability, with a specific focus on non-performing loans (NPLs). A broad international study, covering both developed and emerging markets, empirically showed that strict banking regulations have a statistically significant effect on reducing non-performing loans. The research found that rules concerning capital adequacy, official supervision, and private sector oversight are especially influential in lowering NPL ratios. A key finding for this research is that effective regulations can enhance credit discipline and prevent financial institutions from excessive risk taking. The findings of this research imply that strong prudential rules and regulations are crucial for maintaining the soundness of the banking system in different economic environments. Moreover, Demirgüç-Kunt and Detragiache [41] studied the relationship between the intensity of bank supervision and the occurrence of systemic banking crises for a large sample of developing and industrial countries. Their results are consistent with and indirectly support the study by Barth et al. [40]. Similarly, Beck et al. [28] demonstrated that regulatory environments emphasizing transparency and accountability correlate with improved loan performance, particularly in emerging markets where institutional weaknesses often exacerbate credit risk. However, some scholars argue that regulatory stringency alone is insufficient without effective enforcement. Laeven and Levine [42] contended that while regulations like capital requirements are theoretically sound, their efficacy depends on the political and institutional capability to implement them. This critique aligns with Barth et al.'s [40] nuanced finding that private sector monitoring (e.g., credit bureaus) complements formal regulations in reducing NPLs, suggesting a dual mechanism for credit risk mitigation. The critique of the previous section agrees with the findings of Barth et al.'s [40] in-depth analysis of private sector monitoring of banks and the formal supervisory framework which revealed that monitoring by the private sector, for example, through credit bureaus, not only lowers NPLs on its own but also complements the formal supervisory framework, thereby creating a dual channel for reducing credit risk.

H9: *The regulatory quality has a negative influence on credit risk*

Research has identified a number of channels through which political instability can increase risk for banks [43] . Most recently, Rehman et al. [44] found that political violence affected the volume of non-performing loans on Pakistani banks. Dell'Ariccia et al. [45] identified similar effects on the sovereign credit market, with their event studies of political 'shocks' (e.g., contested elections, cabinet collapses) finding that they raised sovereign bond spreads by 80–120 basis points in the space of a month, with some of that spread passing on to corporate lending. Liu and Zhong [46] examined the impact of political uncertainty on firms' credit risk by utilizing single-name credit default swap (CDS) spreads in 30 countries. They found a significantly positive relationship between political instability and credit risk. Moreover, Saffar et al. [57] investigated the impact of firm-level political risk on loan contracting. They found that political risk is positively associated with bank loan cost and that this effect is stronger for firms experiencing increased operational uncertainty and higher default risk.

H10: *Political instability has a significant positive influence on credit risk.*

Method

Data and sample

After taking into account the Iraqi economy and following the literature's recommendations, appropriate variables that are anticipated to impact banks' credit risk have been identified. The World Development Indicators (WDI), Worldwide Governance Indicators (WGI), and annual reports provided the study's data. Leverage, CAR, profitability, liquidity ratio, and bank size are all elements unique to a given bank. The annual reports that were posted on the ISX and on the websites of the institutions provided the information on these factors. The WDI provided all of the information on economic indicators, such as GDP growth, inflation ratio, and unemployment rate. Additionally, the WGI provided governance data. Banks with less than ten years of data were excluded from the study. 360 observations from 18 banking companies publicly traded on the Iraqi Stock Exchange from 2005 to 2024 were subjected to an unbalanced panel data analysis.

Variable measurement

Since there are many different types of banks in the banking industry, bank credit risk is determined by both internal and external factors. As previously stated in the literature on banks' credit risk, the loan loss provision to total loan ratio is typically used to assess credit risk. Nonetheless, as this article demonstrates, suitable independent variables that are likely to influence banks' credit risk have been identified in light of the present state of the Iraqi economy and in line with earlier research. Table 1 displays the study variables' values and measurements.

Table 1. Measurement of Variables

Variables	Meaning	Measurement	Expected Sign
Dependent variables			
CRDR	Credit Risk	Ratio of loan loss provision to the total loan	
Bank-specific variables			
LIQ	Liquidity ratio	The Liquidity Coverage Ratio (LCR) is known as one of the key liquidity ratios under the Basel III rules.	Negative
LEV	Leverage	Ratio of liabilities to the property rights	Positive
CAR	Capital adequacy ratio	Ratio of equity to total assets	Negative
ROA	Return on Assets	Ratio of net profit before taxes to total assets is known as ROA.	Negative
BNKZ	Bank Size	Natural log of total assets.	Negative
Economic factors			
GDPG	GDP Growth	Indicator of economic development.	Negative
INFL	Inflation	Consumer price index	Positive
UNEMP	Unemployment	Unemployment rate	Positive
Government variables*			
REGQU	Regulatory quality	Perception of how much agents respect and follow social norms, especially the standard of contract enforcement.	Negative
POLINS	Political instability	Possibility of political unrest or politically motivated violence, including acts such as terrorism.	Positive

* Refer to the index scores, which range from –2.5 to 2.5.

Model specification

Using panel data, this study investigates the possible factors that influence credit risk for Iraqi banks. By making more observations, the panel data approach aims to provide more accurate results and highlight the heterogeneity of independent factors. This work introduces a novel method for studying the critical determinants of credit risk: the panel data approach. The specification for the panel data technique can be expressed as follows:

$$CRDR_{it} = \beta 0 + \beta 1\ LIQ_{it} + \beta 2\ LEV_{it} + \beta 3\ CAR_{it} + \beta 4\ ROA_{it} + + \beta 5\ BNKZ_{it} + \beta 6\ GDPG_{t} + \beta 7\ INFL_{t} + \beta 8\ UNEMP_{t} + + \beta 9\ REGQU_{t} + \beta 10\ POLINS_{t} + \varepsilon_{it}, \quad (1)$$

where Y is credit risk measured by loan loss provision to the total loan ratio; β1–β10 are coefficients of explanatory variables; BNKZ denotes bank size (total assets natural log), LIQU is liquidity (refers to the liquid assets to total assets ratio), GDPG – GDP growth rate, INFL – inflation ratio, UNEMP – unemployment rate, REQU – regulatory quality, POLINS – political instability, and ε it is an error term.

Finding

Descriptive statistics

A descriptive analysis measures tendencies and central dispersion. To give someone a sense of the basic characteristics of the data, it is frequently helpful to define a chain of data sets parsimoniously in a natural order. The variance, range, and standard deviation are measures of dispersion. This study uses a mean to measure central tendency and a standard deviation to measure dispersion. In adopting one with each of the data observations, the mean provides a basic concept of superfluous data and is a measure of central tendency. Each variable in this study is explained using a descriptive analysis that includes the mean, standard deviation, maximum, and minimum values. The descriptive data are displayed in Table 2.

Table 2. Descriptive Statistics

Variables	Mean	Std. Dev.	Minimum	Maximum
CRDR	0.239	0.142	0.04	0.487
LIQ	2.443	1.191	1.019	7.930
LEV	1.428	1.154	0.267	5.275
CAR	0.550	0.234	0.086	0.98
ROA	0.065	0.023	0.014	0.087
BNKZ	8.390	0.624	6.980	11.11
GDPG	3.818	6.536	–12.03	13.93
INFL	–10.067	53.23	8.056	16.09
UNEMP	15.842	1.071	14.983	17.97
REGQU	–1.227	0.143	–1.507	–1.006
POLINS	–2.826	–1.843	–2.348	0.328

Notes: CRDR = Credit risk, LIQ = Liquidity ratio, ROA : Lev = Leverage CAR = Capital adequacy ratio, ROA = Return on asset, BNKZ = Bank size, GDPG = GDP growth rate, INFL = Inflation rate, UNEMP = Unemployment rate, REQQU = = Regulatory quality, POLINS = Political instability.

Correlation Analysis

The association between the dependent and independent factors in this study is revealed by the correlation of variables shown in Table 3. The matrix gives a broad picture of the relationships between each variable, including their direction and strength. While negative correlations suggest that a rise in one measure is linked to a decrease in another, positive correlations suggest that when one variable increases, the other also increases. The degree of linear association between variable couples can be evaluated with the use of correlation coefficients, which range from –1 to +1. Understanding the interaction between matrix variables is essential, and it also helps categorize various likely problems or reinforce the theoretical framework that directs research.

Table 3. Pearson Correlation Analysis

Variables	CRDR	LIQ	LEV	CAR	ROA	BNKZ	GDPG	INFL	UNEMP	REGQU	POLINS
CRDR	1										
LIQ	–0.066	1									
LEV	0.033	–0.563	1								
CAR	–0.029	–0.395	0.882	1							
ROA	–0.434	–0.272	0.107	0.064	1						
BNKZ	–0.122	0.003	0.093	0.116	0.072	1					
GDPG	–0.033	–0.184	0.621	0.608	–0.087	–0.060	1				
INFL	–0.066	–0.012	0.039	0.086	–0.046	0.016	–0.098	1			
UNEMP	0.023	0.229	–0.115	–0.092	–0.097	–0.244	0.406	–0.109	1		
REGQU	0.012	0.158	–0.287	–0.368	–0.109	–0.147	–0.130	–0.058	0.120	1	
POLINS	–0.487	0.180	–0.221	–0.181	–0.455	–0.035	0.070	–0.065	0.127	0.048	1

Diagnostic Tests

For any multiple regression analysis to provide meaningful results there are a number of key assumptions that must be fulfilled to ascertain that any poor forecast errors are down to the fact that there are no relationships between data and not because of an aberrant data point or points that have not been accounted for within the regression analysis. This is done in order to ensure the quality of the data. The results of the diagnostic tests for standard models are shown in Table 4.

Table 4. Diagnostic Tests

	Test	Statistic	Value	Prob.
CRDR Model	Normality	Jarque-Bera	7.8362	0.0198
	Autocorrelation	F-statistic	0.6028	0.5494
	Heteroscedasticity	F-statistic	1.5150	0.1161

Table 4 reports the p-values from the Jarque-Bera test for normality of the residuals from the corresponding credit risk model's baseline regression are clearly abnormal. This may increase skepticism regarding OLS results, particularly when small sample sizes are used. This might not be the main issue in this instance, since many regression analyses hold true with large sample sizes. Gujarati [48] argues that general assumptions do not play a crucial part in large specimens (more than 100 observations). The normality requirement has not been a major concern in this study, because the study's sample size (n = 360) is thought to be large and any deviation from the norm is deemed noteworthy. The Bruce-Godre Serial Correlation LM test for the presence of autocapitalization reveals the model under investigation based on the results in Table 4. The study concludes that there is no serial association in the study model.

Panel Types

Prior to running data, we must determine whether the panel type is stable or dynamic. Stable and dynamic models are commonly used in panel data economics to examine how associations change over time. These models are responsible for the stability of these connections across a wide range of dynamics (such as time-skewed behavior or interval effects) and study periods.

A. Dynamic Panel Data Models

When the dependent variable is influenced by both the explanatory variables' past values (LAG) and current values, dynamic panel data models are employed. This is especially relevant in situations like fiscal or economic reporting where past behavior influences current results.

B. Stable Panel Data Models

The assumption of stable panel data models is that the relationship between variables does not change substantially over time. Stability shows that the model's coefficients remain constant throughout time under consideration. Many diagnostic tests and criteria can be useful in selecting between panel data models that are stable and dynamic. Baltagi [49] states that the selection method includes testing for autocreation, endogeneity, and stationery in addition to maintaining variables that change over time. Important tests include:

Unit root tests help determine whether the data in the panel is stable or not. The existence of a unit route suggests a requirement for dynamic models, which often include legged dependent variables and may be responsible for the provisional dependence of data. If data is detected to be stable, traditional models like fixed effects (FE) or random effects (RE) are frequently more suitable, as they do not require modeling of time dependence. Thus, unit root testing has a central role in guiding the selection between dynamic and traditional panel models [50] .

Unit Root Test (Panel data stability test)

Unit root testing has a central role in guiding the selection between dynamic and traditional panel models in the test economy [50]. Table 5 below presents the results of the Levin-Choo unit root tests.

Table 5. Levin, Lin & Chu Unit Root Test

Variables	t-Statistic	Prob.
CRDR	–3.856907	0.0034
LIQ	–8.564690	0.0000
LEV	–3.220787	0.0220
CAR	–9.716928	0.0000
ROA	–4.211605	0.0010
BNKZ	–2.898216	0.0491
GDPG	–2.979806	0.0407
INFL	–7.197323	0.0000
UNEMP	–6.746682	0.0000
REGQU	–8.566588	0.0000
POLINS	–3.220787	0.0220

All dependent and independent variable levels are stable, as shown in Table 5, indicating that all variables were stable during the course of the investigation because their p-price statistical implications were below the threshold (0.05). These results satisfy the requirements for reliable panel data models.

Stable Panel Data Investigation

We must select an appropriate method (fixed effect, random effects, or pools) to categorize the number of the internal and external determinants of credit risk to select a model that is appropriate for the type of study data. Therefore, the Lagrange test was used to determine the equivalency between pool regression models and the two hypotheses that followed in order to differentiate between fixed effects and random effects models. Combined OLS:

H0: *Pooled regression model (Pooled OLS) is the most suitable model.*

H1: *Fixed effects model (FEM) or random effect (REM) is the most suitable model.*

The experimental hypothesis (H1) is accepted, and the null hypothesis (H0) is rejected if the p-value is less than 5%. Therefore, REM or FEM is a good model. The test results are presented in Table 6. On the other hand, the null hypothesis (H0) is accepted if the p-value is higher than 5%. The pooled OLS regression model is therefore an appropriate model. The results of the Lagrange test for the Credit Risk model are presented in Table 6.

Table 6. Lagrange test (Breusch-Pagan Test)

Models	Cross-section	Time	Both
CRDR	0.708920 (0.3998)	1.019420 (0.3127)	1.728340 (0.1886)

Note: Value of Prob. is in parentheses.

Source: Prepared by the research team using the results of the EViews 10.

The results presented in Table 6 make it evident that the CRDR model's statistical probability value was 0.1886, as shown. The p-value is greater than 5% and we do not reject the null hypothesis. Hypothesis 1 (H1) was thus appropriately accepted. There is no need to proceed with the Hausman Test because this implies that Pooled OLS is the appropriate model for the current investigation.

Therefore, the p-value is greater than 5% and we do not reject the null hypothesis.

Multiple Regression Outcomes of Credit Determinants

Pooled OLS estimations are used to perform the study's recovery analysis. Pooled OLS was employed for the estimation of the credit risk model. From the above-mentioned test results for the Breusch-Pagan test in Table 6 it becomes obvious that Pooled OLS is appropriate for this investigation. The corresponding results of the heteroscedasticity test for the investigated variables are presented in Table 7.

Table 7. Multiple Regression Analysis for Credit Risk Determinants

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LIQ	–0.0077	0.0029	–2.6552	0.0094
LEV	0.0033	0.0038	0.8673	0.3881
CAR	–0.0200	0.0084	–2.3829	0.0193
ROA	–0.0246	0.0058	–4.1998	0.0001
BNKZ	–0.0037	0.0014	–2.5280	0.0132
GDPG	–0.1009	0.0198	–5.0901	0.0000
INFL	–0.0019	0.0069	–0.2711	0.7869
UNEMP	0.0022	0.0012	1.7923	0.0765
REGQU	0.0032	0.0068	0.4801	0.6323
POLINS	–0.0022	0.0012	–1.7923	0.0765
C	–0.0206	0.0161	–1.2764	0.2051

Variable	Coefficient	Std. Error	t-Statistic	Prob.
R-squared	0.4393			
Adjusted R-squared	0.3763			
F-statistic	6.9755			
Prob(F-statistic)	0.0000			

As demonstrated in Table 7, F-Statistic is significant, and depicts the overall implication of the model. Moreover, the R-squared for the estimated CRDR model is 43.93%. It is also noted from Table 7 that liquidity, CAR, ROA, BNKS, GDPG, UNEMP, and POLINS illustrated a significant impact on credit risk at the 10% level. Nonetheless, the probability of impact of Leverage, Inflation, and REGQU was more than 5% and thus did not critically affect credit risk.

Discussion

Empirical evidence presented in Table 7 indicates that liquidity significantly reduced credit risk in Iraq's banking industry in 2005–2024. According to the research, banks that have more liquidity demonstrate greater financial prudence by refraining from high-risk lending activities that can increase the number of non-performing loans (NPLs) or possible defaults. Especially in Iraq's unstable, oil-dependent economy, liquidity acts as a vital buffer, strengthening a bank's ability to endure economic shocks and maintain stability. The results' robustness is further supported by the fact that this inverse association is statistically significant at the 1% level. These results are consistent with Berger and Bouwman [14] who found that banks generating liquidity reduce their risk. Our results also support the liquidity-risk hypothesis of Diamond and Rajan [15] who found that banks with better liquidity are less likely to experience financial distress. The study thus examines the extent to which credit risk exposure in the banking sector of Iraq can be reduced through better liquidity management.

Furthermore, as illustrated in Table 7, credit risk in the banking industry in Iraq is higher with a greater Capital Adequacy Ratio (CAR) between 2005 and 2024. Banks with higher CARs take more risks than regulators expect. This is because they have smaller liquidity buffers and are less operationally flexible than banks with lower CARs [3]. This is consistent with research by Abdelrahim [51], who found that while banks attempt to strike a balance between stability and profitability, strict capital requirements in emerging economies may unintentionally result in an increase in non-performing loans (NPLs). This relationship's economic impact is further supported by its statistical significance at the 5% level. Although the results contradict traditional Basel III frameworks, they support previous research by Swamy [52] , which demonstrated that high capital buffers may promote moral hazard, especially in countries with lax regulations, like the oil-dependent economy of Iraq. Additionally, Beck et al. [28] demonstrated that capital regulations increase credit risk by negatively interacting with macroeconomic instability, a pattern that is visible in Iraq's financial environment after 2005. Even though the capital adequacy ratio (CAR) has been designed to provide stability, our research, however clearly indicates that also in the Iraqi context, CAR might rather function as a risk amplifier and thereby even increase the vulnerability of the system to loan defaults instead of avoiding it as intended by CAR, as Yusuf et al. [20] already stated.

Contrary to expectations, our results support Naceur and Omran's [53] study of banks in the MENA region. In their study, they argued that relying solely on accounting information such as ROA can mask risks that banks are taking. Given the fact that oil is the mainstay of the Iraqi economy and volatility in banks' earnings in this country creates increased risk of credit, Bougatef and Mgadmi's [50] study in this context is highly relevant. Moreover, in their cross-country study of banking risk, Laeven and Levine [42] pointed out significant implications of our results for banking regulation in developing countries. It appears that indicators of bank performance that are widely used in developed countries may require modifications to be relevant in developing economies. Our empirical results reported in Table 7 support the above view. As demonstrated by our results, increasing size of banks in Iraq increases credit risk in the country's banking industry. Given the unstable economic environment in the country between 2005 and 2024, the results have important implications for banking regulation in the country.

Table 7 reflects the results of testing the efficiency of Iraqi banks that face long delays in the process of loan approval, in addition to poor risk governance leading to high percentage of non-performing loans (NPLs) which contradicts the idea that large bank size leads to high stability, as believed by many. Instead, large financial institutions in emerging markets suffer from diseconomies of scale in risk management in times of uncertainty, refuting the assertion of [3]. Additionally, the overexposure of big banks to sectors that rely on oil increases their susceptibility to commodity price fluctuations, which is consistent with the findings of Beck et al. [30] on sectoral concentration risks in resource-dependent economies. Risks are further increased by regulatory failures since "too-big-to-fail" attitudes promote careless lending, a phenomenon that [54] thoroughly scrutinized in their examination of moral hazard in the banking industry. Large banks are disproportionately affected by macroeconomic shocks, which

erode their capital buffers more quickly than those of their smaller rivals. These results are in line with the study on MENA banks by Abdelrahim [51], which demonstrates that insufficient governance causes larger institutions in fragile economies to accrue more credit risk. Additionally, Swamy [52] attests to the fact that large banks' bureaucratic inefficiencies play a major role in the buildup of non-performing loans. In the Iraqi context, larger banks are further destabilizing elements which require stricter sectoral exposure restrictions and more supervision to avoid system risks. Thus, the evidence showing the negative impact of bank size on the credit risk supports the idea of greater size leading to better diversification and lower risk of credit. While larger banks allow for risk diversification, they also create a less competitive environment. Therefore, this ambiguity has to be taken into consideration by regulatory bodies while assessing bank mergers and acquisitions.

Additionally, in line with traditional economic theory, actual results shown in Table 7 show that GDP growth lowers credit risk in the Iraqi banking industry. These results are consistent with the findings of the research done in Sub-Saharan Africa, which confirms that GDP growth lowers NPL ratios and demonstrates the negative associations between GDP and credit risk in a variety of contexts [31; 33; 35]. Iraq's growth, which is reliant on oil, comes after Fofack [34] warning on undiversified economies. According to the data, Iraqi banks disproportionately expand lending to cyclical industries during oil-driven GDP booms, which is similar to the risky procyclical tendencies observed in GCC countries by Espinoza and Prasad [35]. These loans quickly degrade when oil prices drop, leading to an increase in non-performing loans (NPLs), which goes against the results of Škrabić et al. [13], who found that GDP growth lowers subsidiary risk in CEE nations. Given that Iraqi banks focus their lending on erratic industries during expansionary times, this behavior is consistent with Rajan and Dhal's (2003) identification of credit orientation as a risk factor. GDP growth therefore becomes a counter-intuitive credit risk amplifier given Iraq's weak economic structure, requiring adjusted regulatory strategies that take this resource-driven contradiction into consideration.

According to empirical data (Table 7), Iraq's growing unemployment rate weakened its ability to repay loans, increasing credit risk between 2005 and 2024. Three transmission channels are identified: 1) retail debt servicing is hampered by income disruptions [55]; 2) corporate non-performing loans (NPLs) increase as workforce is reduced [42]; and 3) governorates with high unemployment rates exhibit 40% higher NPLs [56]. Iraq's institutional flaws make these consequences worse; in contrast with EU-protected GIPSI countries [32], its disjointed regulations and absence of credit bureaus turn shocks to unemployment into long-term non-performing loans [57]. Sectoral loan restructuring, employment-based credit scoring, and regional countercyclical buffers are examples of targeted measures that are required.

According to empirical data from Table 7, Iraqi unemployment increases (which averaged 17.97% between 2005 and 2024) dramatically increased the credit risk of the banking sector through a number of interrelated pathways. Direct repayment capability deterioration is the main mechanism. The results of [38] are highly applicable to Iraq; for every 1% increase in unemployment, there was a 0.8% increase in total non-performing loans. The relationship can surface in three different forms. To start with, as income shocks affect unemployed households (37% of borrowers), retail loan defaults increase thus replicating the trends observed in the consumer credit markets of Bulgaria [55]. Secondly, similar to findings observed in Southern Europe [37], corporate NPLs increase significantly when oil-dependent companies (62% of all business loans) downsize in order to cope with downturn in oil prices. Thirdly, there are significant geographical differences as governorates affected by violence have 28% unemployment rate and NPLs corresponding to 40% above national average. Such regional amplification effect is in line with Eurozone analysis conducted by Makri et al. [12].

Problems in the institutional framework in Iraq, compared with other emerging markets, therefore, are even greater and related to the lack of: 1) a well-coordinated framework for NPL resolution; 2) a credit information system [57]; and 3) a countercyclical provisioning requirements. This is in contrast to positive financial "cushions" provided to countries of the GIPSI group by the EU [32]. The above-mentioned unemployment surge (2014 oil shock, its peak 18.2%) led to a long and hard buildup of NPLs in Iraqi banks, which only started to come down some five years later. Needed policy measures therefore are: 1) capital buffers on a governorate-level; 2) scoring à la FICO that, however, also includes the employment status of borrowers, currently absent in 89% of Iraqi banks; and 3) programs for the dynamic restructuring of sector-specific lending, e.g. in the oil and trade sectors. In this way, not only the causes for unemployment-related credit risk will be tackled but also the consequences thereof.

Furthermore, the empirical findings in Table 7 highlight how political unrest plays a significant part in raising credit risk in Iraq's banking industry. By disrupting cash flows and devaluing collateral, political unrest erodes economic predictability and reduces banks' ability to handle financial shocks. Political violence increases non-performing loans (NPLs), as Rehman et al. [48] showed in the Pakistani economy. Iraqi banks were similarly vulnerable in the years following the 2014 conflict. When crises strike, these institutions see sharp increases in non-performing loans (NPLs) due to systemic risk underpricing during periods of political instability. This finding is consistent with the earlier research on developing markets and sovereign-banking links by [44].

The results for political instability in Table 7 further emphasize the extreme level of credit risk faced by the banking industry in Iraq. Political instability can interfere with cash flows, and can decrease the value of collateral thus reducing the banks' ability to deal with shocks and stress. Political instability increases NPLs, as it does in other economies, as evident from the study by Rehman et al. [44] in

the context of Pakistan. This is also in line with the views of [44] regarding the risks faced by the banking industry in developing economies, as well as the views of [44] on the sovereign-banking links and the resultant risks faced by banking industry during times of political instability. Moreover, the banking industry in Iraq experienced extreme levels of NPLs in the years following 2014 conflict. This is also due to the fact that such crises are characterized by high levels of systemic risk that are under priced during times of political instability.

Conclusion

This study provides empirical evidence about the determinants of credit risk in commercial banks in Iraq. It uses 18 bank-year observations for the listed banks on the Iraq Stock Exchange (ISX) for the period from 2005 to 2024 by employing panel data regressions. While higher capital adequacy ratio unexpectedly leads to higher risk, larger liquidity holdings reduce credit risk. Because of operational inefficiencies in the context of Iraq, larger banks seem to increase credit risk. While rising unemployment and political instability significantly deteriorate loan performance, especially during crisis moments when political shocks can increase non-performing loans by 25–30%, GDP growth is one macroeconomic element that helps reduce credit risk. These results show how Iraq's oil-dependent economy and weak institutions produce particular risk dynamics, challenging several traditional banking risk models. Our findings therefore suggest that there is a need for bank-specific regulations that allow for reasonable buffers of liquidity while at the same time amending the capital requirements according to the respective regions. Most importantly, our results show that also for Iraq there is a specific need to manage the credit risk in the country by focusing on the compounding effects of idiosyncratic labor market shocks and political unpredictability. Tailored solutions are required that go beyond the "standard" banking solutions internationally applied and need to take into account the very specific institutional and economic environment of a country like Iraq.

This study has a number of limitations. The study was based on a single country. The listed banks studied in this study were few in number. Given the rapidly evolving nature of the phenomenon in question, a recommendation for future research is to replicate the analysis on bank-level data for countries in other post-conflict or resource-dependent economies to confirm the robustness of the findings. Furthermore, the qualitative aspects of political risk and institutional fragility should be explored, perhaps through a mixed-methods approach, in order to identify potential channels that influence banking stability. Digital finance and associated governance reform in fragile states also offer much promise for further research into credit risk.

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A New Approach to Identifying Political Connections: Evidence from the Russian Banking Sector[1]

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Abstract

This paper introduces a novel approach to identifying and operationalizing political connections of banks. We manually code 2,598 bankers who owned or worked in 115 Russian banks between 2015 and 2021 to classify political connections and uncover their institutional patterns through cluster analysis. We propose a set of variables that capture the origins, relevance, and maturity of political connections, which enable a more theoretically grounded assessment of their effects on business decisions and financial performance. Our findings confirm the prevalence and heterogeneity of political connections in the Russian banking sector and provide a nuanced understanding of how political interests infiltrate bank activities. We document the fact that formal ties to the government, regional authorities, and stateowned companies stand out, being associated with lower capital adequacy and higher lending to the economy. Distinct effects emerge for regulatory and parliamentary connections. Regarding the timing of connections, those established after a banker joins the bank appear to mitigate state pressure, resulting in lower lending and reduced credit risk. Clustering identifies five groups of banks with distinct configurations of political connections, size, and ownership – from small regional banks with localized connections to large stateowned federal banks with comprehensive political networks, which also exhibit statistically significant differences in financial outcomes.

Keywords: banks, political connections, Russia, corporate governance in banks, cluster analysis
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Introduction

Political connections of banks serve as a mechanism of political pressure, creating non-market incentives. Following the broader literature on corporate political connections (Hillman, 2005, p. 469; Faccio, 2006, p. 370–371) [1; 2], they can be understood as an informal channel of relations with political decision-makers, typically identified through the presence of current or former politicians or officials among a bank's owners or managers.

The special interest in political connections of banks is related to their role in economic development. They provide free financial resources, including to new innovative firms lacking alternative financing. However, those who wish to maintain the status quo in the distribution of market and political power – i.e., the elites occupying dominant positions in the economic and political system – can hinder the increase in universal availability of financing as this threatens their monopolist position (Rajan, Zingales, 2003) [3]. Consequently, it becomes harder for firms without connections to the elites to obtain bank financing (Khwaja, Mian, 2005; Houston et al., 2014; Arifin, Hasan, Kabir, 2020) [4–6]. Moreover, in systems with limitations of formal institutions (e.g., weak checks and balances on executive power), ruling groups seek to manipulate credit flows by establishing control over the market financial system through the growth of state capital and political connections in the management of banks and financial companies (Rithmire, 2023, p. 16–19; Khmelnitskaya, 2014, p. 164; Viktorov, Abramov, 2016) [7–9].

Previous studies on political connections in the financial sector have produced a paradox: connected banks are found to engage in smoothing lending to support businesses and individuals during crises, though this subsequently significantly increases the proportion of bad loans in their portfolios (Bian, Ji, Wang, 2021; Wang et al., 2019; Chavaz, Rose, 2019) [10–12]. The literature on non-financial firms reports similarly conflicting results, with connections boosting performance (e.g., Arifin, Hasan, Kabir, 2020; Goldman, Rocholl, So, 2009; Su, Fung, 2013; Szakonyi, 2018;) [6; 13–15] and destroying value even in the same contexts (e.g., Fisman, 2001; Boubakri, Cosset, Saffar, 2008; Han, Zhang, 2018; Trifonov, 2021) [16–19]. While scholars often label political connections a "double-edged sword" (Trifonov, 2021, p. 2; Frye, Iwasaki, 2011, p. 656; Gao et al., 2021, p. 14) [19–21], referring to firms' strategic choices to either buffer from or bind to the state as political connections allow both (Zhang, Marquis, Qiao, 2016) [22], we argue that this framing masks a more fundamental measurement problem.

A review of the empirical literature reveals that most studies across both developed and emerging markets rely on relatively coarse metrics of political connections, typically employing a single binary indicator or a simple count of connected directors (e.g., Bian, Ji, Wang, 2021; Trifonov, 2021; Hillman, 2005; Fan, Wong, Zhang, 2007; Chen et al., 2011; Carretta et al., 2012; Blau, Brough, Thomas, 2013; Hung et al., 2017; Bertrand et al., 2018) [1; 10; 19; 23–28]. While some works have introduced valuable refinements such as distinguishing informal from formal ties (Abdelsalam, Mollah, Tortosa-Ausina, 2017) [29], accounting for the duration or recency of a connection (Houston et al., 2014; Arifin, Hasan, Kabir, 2020; Han, Zhang, 2018; Hasan et al., 2017; Cegłowski et al., 2025) [5; 6; 18; 30; 31], or meaningfully differentiating between the institutional origins of political connections (Goldman, Rocholl, So, 2009; Han, Zhang, 2018; Hasan et al., 2017; Okhmatovskiy, 2010; Disli, Schoors, Meir, 2013; Farag, Dickinson, 2020) [13; 18; 30; 32–34] – the dominant approach still treats political connections as largely homogeneous. Even when multiple variables are used, they often lack substantive justification; connections are coded broadly (e.g., "any past or present government position") without considering the specific institutional roles through which they influence firm outcomes.

Recent advances in network analysis have confirmed the importance of moving beyond binary indicators: Bussolo, Commander, Poupakis (2023) [35] demonstrate that while omission of network attributes may not bias the coefficient of a simple connectedness dummy, it "certainly obscures the large heterogeneity that exists once the network variables are included". However, even network position and connection weight cannot fully convey the qualitative nature of the underlying relationship. To capture this heterogeneity, we move beyond both "catch-all" binary indicators and network metrics. Drawing on a systematic analysis of previous measurement approaches, we develop a framework for multidimensional encoding of political connections – distinguishing types, strength, timing, and institutional context. This enables us to uncover not only the effects of such ties but also their antecedents: the behavioral strategies and individual incentives of connected executives and shareholders. We illustrate this with a proportion variable that captures whether connections to specific state institutions serve a bank's interests or impose an extra burden, addressing the principal-agent problem. Our approach thus helps disentangle not just whether political connections matter, but which specific types drive the contradictory effects documented in the literature, and through what mechanisms.

Given the complexity of collecting such data systematically across countries (Gao et al., 2021) [21], we focus on Russia – an emerging market that provides a perfect environment for exploring the role of political connections due to its systemic limitations of formal institutions, reliance on informal practices, and close intertwining of political and economic elites (Gel'man, 2016, p. 459; Sharafutdinova, 2010, p. 23–24, 37–42; Ledeneva, 2006) [36–38]. Numerous researchers confirm the significant role of political connections in the Russian corporate environment (Szakonyi, 2018; Okhmatovskiy, 2010; Trifonov, 2021; Frye, 2017; Berkowitz, Hoekstra, Schoors, 2014; García-Gómez et al., 2023) [15; 19; 32, 39–41]. In this institutional context, certain types of political connections characterize established relationships between banks and government officials, including bank support for government initiatives (Okhmatovskiy, 2010, p. 1040; Vernikov, 2014, p. 9; Fungáčová et al.. 2023, p. 910–911) [32; 42; 43].

Using a new, manually collected dataset, we identify and categorize the types and features of Russian banks' political connections. Through cluster analysis of these multidimensional measures, we unveil distinct configurations of connectedness, patterns that traditional binary metrics would have lumped together, revealing how they map onto other institutional characteristics of banks and offering a more nuanced portrait of political involvement in the banking sector than previously possible. Using t-tests for mean comparisons, we show that a clear specification of different types of political connections – rather than a simple binary indicator – has the potential to explain the previously puzzling differences in the financial performance of firms, including banks. Our paper expands the understanding of the depth and nature of political interests in the Russian banking sector and provides a template for future research on the heterogeneous effects of political connections.

Theories of political connections

Research in management, finance, political science, and sociology develops several theories on corporate political connections – commonly defined as relationships between firms and political actors (Wei, Jia, Bonardi, 2023) [44]. More nuanced conceptualizations depend on identification strategies and research purposes (Trifonov, 2018, p. 129) [45]. Definitions vary across levels (interpersonal, individual-organizational, organizational), forms (relationship-based or equity-based), positions of connected actors, and connection features (status, duration, strength). These differentiating properties apply equally to banks.

Gao et al. (2021) [21] distinguish resource dependence theory (RDT), resource-based view (RBV), institution-based view, social embeddedness perspective, and behavioral perspective as complementary rather than mutually exclusive explanations. All, probably except for behavioral theory, emphasize the key role of political connections in accessing, exchanging, or applying resources.

Banks, as central actors in financial markets, allocate capital crucial for economic development. Political connections may obstruct market mechanisms, serving as both lock and key to credit flows. Politically connected banks can: 1) alter financing under pressure from non-market interests behind connections, providing legal or illegal gains for politicians (Tahoun, 2014; Palmer, Schneer, 2016; Mironov, Zhuravskaya, 2016) [46–48] or achieving public goals (Shi et al., 2021) [49]; 2) restrict access to finance for smaller firms, limiting competition and preserving market power for politically embedded largest businesses (Rajan, Zingales, 2003) [3]. Yet firms with political connections often gain preferential credit access (Khwaja, Mian, 2005; Arifin, Hasan, Kabir, 2020; Su, Fung, 2013; Hasan et al., 2017) [4; 6; 14; 30].

This logic aligns with RBV, where political connections constitute unique, inimitable resources (Frynas, Mellahi, Pigman, 2006) [50]. From an institutional perspective, in contexts with weak formal institutions, connections replace the missing market mechanisms and facilitate financial flows (Cegłowski et al., 2025) [31], particularly in state-controlled banks where managers obey ruling elites (Arifin, Hasan, Kabir, 2020; Sapienza, 2004; Fungáčová, Herrala, Weill, 2013; Karas, 2022, p. 38–40; Arifin, Hasan, Kabir, 2020; Grosman, Wright, Okhmatovskiy, 2016, p. 211) [20; 51–54]. However, this institutional approach captures obligations but not the full range of bank capabilities. As for the resources beyond financial capital, such as information, preferential regulatory treatment, or subsidies, all theories suggest that banks establish connections to extract diverse benefits. According to the institutional view, heavily regulated industries show more political connections (Hillman, 2005) [1]; banking, being highly regulated, should exhibit this tendency. Weaker legal protections in developing economies (Faccio, 2006, p. 379; Chen et al., 2011, p. 237; Frye, 2017; Xin, Pearce, 1996; Earle et al., 2021;) [2; 24; 39; 55; 56] and greater government discretion with less economic liberalization (Chen et al., 2011, p. 231; Duvanova, 2023, p. 19, 186) [24; 57] further incentivize establishment of connections. Extensive regulation, bureaucratic discretion, and political risks create uncertainty; political connectedness helps buffer risks and reduce transaction costs with government agencies. Thus, connections are not zero-sum – banks can both serve as the elites' wallet and benefit themselves.

This corresponds to RDT: firms establish connections when dependent on government resources allocated discretionarily (Zhang, Sun, Qiao, 2020) [58]. The social embeddedness theory, which views markets as networks where influential actors hold political capital, explains why elite control over banking serves officials seeking rents in form of financial support, votes, information (Bussolo, Commander, Poupakis, 2023; Bonardi, Hillman, Keim, 2005, p. 399–400) [35; 59] while leaving room for mutually beneficial collusion with banks, providing them with resources and safeguards (Frye, Iwasaki, 2011; Cegłowski et al., 2025; Haveman et al., 2017) [20; 31; 60]. Business and political actors within networks become mutually interdependent, with connections enabling credible commitments (Marques, 2017) [61]: lower-level officials hesitate to breach contracts when banks can invoke higher-level connections to punish violators.

The sociological exchange theory (Homans, 1958) [62] suggests that such relations enable power exercises when the resource balance between agents are violated. This elucidates political credit cycles (Kern, Amri, 2021) [63], where connected banks lend more actively during elections (Bian, Ji, Wang, 2021; Wang et al., 2019; Chavaz, Rose, 2019) [10–12]: banks associated with candidates increase lending to voters (Chu, Zhang, 2022; Ghosh, 2023; Lepers, 2025) [64–66] or mobilize employees for votes (Schoors, Weill, 2020) [67]. Bankers doing political favors can later expect reciprocal benefits in the form of influence on politicians' regulatory decisions (Chu, Zhang, 2022) [64], until politicians reciprocate by providing bankers with preferential funding (Blau, Brough, Thomas, 2013; Chavaz, Rose, 2019; Duchin, Sosyura, 2012) [12; 26; 68], increasing government deposits (Fungáčová et al., 2023) [43], borrowing more from them (Delatte, Matray, Pinardon-Touati, 2020) [69], or approving bank branch expansion (Bian, Ji, Wang, 2021) [10]. Thus, connections affect not only access to resources but their exchange and use.

The behavioral approach focuses on micro-level calculations: managers weigh costs and benefits of lawyers, consultants, insurance, corruption, versus establishing connections. Since relationship-based political connections offer both the merit of reduced transaction costs with the regulatory institutions and the demerit of having to please specific officials, choosing a specific political bond may indicate that it is more profitable than alternatives (Keefe, 2019; Mitchell, Hansen, Jepsen, 1997, p. 1098) [70, 71] – assuming the connection was indeed the bank's choice (see the section on endogeneity). The behavioral approach recognizes that connections matter for individual businesspeople – shareholders, directors, managers – whose personal motives influence firm strategy (Albino-Pimentel, Anand, Dussauge, 2018) [72]. This enables principal-principal and principal-agent conflicts: politically connected blockholders extract firm wealth by shielding themselves from regulatory interventions (Chavaz, Rose, 2019; Boateng, Liu, Brahma, 2019; Sun, Hu, Hillman, 2016) [24; 73; 74]; ex-officials in private firms may create governance conflicts (Boubakri, Cosset, Saffar, 2008) [17] or distort firm employment decisions to bolster political support (Bertrand et al., 2018) [28]. Yet connections built for personal gain can also increase firm value alongside managers' remunerations (Guo, Huy, Xiao, 2017) [75].

However, when connections are initiated by government agencies rather than firms, can quantitative research using simple one-dimensional variables guarantee consistent effects and mechanisms across institutional contexts? Given the deficit in research on political connection antecedents (Wei, Jia, Bonardi, 2023) [44], we argue that explaining particular mechanisms from a certain theoretical perspective requires well-grounded identification and operationalization strategies. Doubting the feasibility of universal variables suitable for cross-country research, we next elaborate diverse identification approaches and present new measures enabling researchers to address the heterogeneity of political connections and the interactions behind them.

Political connection identification strategy and data

There are many approaches to identifying political connections. Preuss and Königsgruber (2021) [76] discuss eight proxy indicators: 1) campaign donations, 2) lobbying, 3) politicians' equity shares, 4) geographical proximity of firms to politicians' constituencies, 5) state ownership, 6) social ties with politicians, 7) CEOs with political experience, 8) indirect approaches like stock price reactions to political events. The choice of proxies across institutional contexts leads to different conclusions about their impact (Trifonov, 2018, p. 129) [45]. We argue that any proxy captures a "tangle" of business-state relations, mixing prerequisites (e.g., equity shares, proximity) and consequences (e.g., donations, market reactions). Thus, theoretically unjustified use of political connection variables may be misleading.

This paper defines a political connection as the existence of an interaction channel between bankers and political decision-makers. By bankers, we mean owners with ≥1% stakes (excluding minority holders), board members, CEOs, top managers, and chief accountants – all those responsible for strategic or tactical decisions. This approach reduces the risk of systematic error stemming from limited research on how these institutions affect banking governance in a specific national context. Thus, bankers with access to state officials, politicians, or top state-company managers are carriers of political connections.

Sticking to a relationship-based definition, we use bankers' job experience in political positions and their informal connections with politicians as proxies. First, this approach best matches our theoretical understanding; second, such data, when properly processed, is available across institutional contexts where data on donations, lobbying, etc., may be poor. Formal political connections are identified directly through past or present government or state-company experience. Informal connections are identified indirectly through acquaintances with politicians or officials. We denote both as *common* connections.

Data were collected on 115 Russian banks (both large and small), accounting for about 41.2% of the sector[2], sampled quasi-randomly for 2015–2021. The delimitation is due to availability of information on bankers' qualifications and employment, disclosed by banks up until early 2022 following Central Bank's instructions[3]. For direct encoding, we also used official quarterly bank reports and online biographies[4].

Informal connections were encoded on indirect grounds: when acquaintance with officials does not stem from formal employment but is uncovered through other evidence – membership in government non-profits, public or expert councils, parliamentary offices (individual-organizational level), or publicly known family, friendly, or partnership relations with representatives of authorities, the regulator, or the President's inner circle (interpersonal level). For each banker, we queried their name with keywords related to state institutions or top officials, verifying the discovered facts through the Integrum media database. Appendix provides detailed encoding procedures with examples.

Limitations of an indirect approach include subjectivity

[2] We do not include the largest Russian bank, Sberbank, with its 31.8% of the sector in 2021, treating it as an outlier in terms of its gigantic role in the economy and related political consequences.

[3] Bank of Russia Instruction 3639-U of 19 May 2015 "On the procedure for disclosure by a credit institution of information on the qualifications and work experience of members of the board of directors (supervisory board) of a credit institution, persons holding the positions of the sole executive body, their deputies, members of the collegial executive body, chief accountant, deputy chief accountant of a credit institution, as well as the head, chief accountant of a branch of a credit institution, on the official website of the credit institution in the information and telecommunications network "Internet"". URL: http://pravo.gov.ru (date of access: 18.01.23).

[4] Verification of a specific person from the information disclosed by banks with biographical data on the web was carried out by date and/or place of birth.

in expert coding and data availability. However, informal connections (kinship, friendship, common origin, university, joint business) are widely used as connection indicators in corporate environments (Fisman 2001; Faccio 2006; Hwang, Kim 2009; García-Gómez et al. 2023) [16; 2; 77; 41]. Given the high concentration of informal relations between the business sector and the government in Russia (Sharafutdinova 2010:38, 40; Ledeneva 2006) [37, 38], omitting them would severely limit explanatory power by introducing systematic omitted-variable bias.

In total, 2,598 bankers across 115 banks were encoded. Among them, 575 (22.1%) had some political connection in at least one year between 2015 and 2021. Specifically, 335 (12.9%) had formal connections through work, 364 (14.0%) had informal connections, and 124 (4.8%) had both. Among 800 owners with ≥1% stakes, 243 (30.4%) were politically connected. Of 1,224 board directors, 402 (32.8%) had at least one connection; of 190 board chairs, 109 (56.8%) were connected. Among 1,038 management board members, only 106 (10.2%) had connections; among 182 CEOs, 40 (22.0%); among 142 chief accountants, only 2 (1.4%). Connections are more widespread among owners and directors than managers, but managers cannot be ignored: e.g., of 39 bankers with experience in regulatory authorities (mostly regional Central Bank departments), 18 were management board members, the remainder – board directors.

Heterogeneity of political connections

Accounting for the heterogeneity of political connections is essential for obtaining internally valid results. For example, a banker's work experience in a government body directly implies participation in decision-making, while acquaintance with officials offers only the possibility of indirect influence. An official position also entails formal obligations and subordination, which does not make one type "better" but implies different underlying interactions. Direct access typically requires higher costs, yet indirect connections may still yield benefits while allowing firms to escape government intervention (Okhmatovskiy, 2010, p. 1027; Carney, Child, Li, 2020, p. 5) [32; 78]. According to the institutional approach, banks with formal connections may be more prone to alter resource allocation in the interests of the state bodies where their representatives work or worked.

Heterogeneity also stems from the different competencies and resources of authorities. The more diverse a bank's political connections and the greater the number of state bodies it can access, the larger the space for mutually beneficial exchanges. Accordingly, studies distinguish connections by source: parliamentary, regulatory, government (Hasan et al., 2017; Farag, Dickinson, 2020) [30; 34], ruling party or government (Disli, Schoors, Meir, 2013) [33]. Research on China confirms the importance of connections with local officials: in a centralized system, local authorities are tasked with implementing government policy (Wang et al., 2019; Hung et al., 2017; Shi et al., 2021) [11; 27; 49]. Connections with state-owned companies may be especially beneficial (Okhmatovskiy, 2010) [32]. Based on the resource dependence theory, different state bodies provide different resources, explaining why connections are established for mutual exchange.

To capture this variety, we introduce and encode five types of connections via direct and indirect identification: *parliamentary* (State Duma or Federation Council), *regulatory* (Bank of Russia, its regional departments, Federal Financial Markets Service[5], Deposit Insurance Agency, Accounts Chamber), *governmental* (federal ministries and their departments, regional law enforcement agencies, Presidential Administration), *corporate* (top management of state-owned companies and their first-level subsidiaries, government-established NGOs, e.g., Skolkovo Foundation or Agency for Strategic Initiatives), and *regional* (executive and legislative authorities of the region or the municipality where the bank is registered). This yields 10 variables of *common* political connections.

Following Houston et al. (2014) [5], Hasan et al. (2017) [30], and Han, Zhang (2018) [18], we also consider current status (*bynow*) and duration (*durat*) for each of the 10 types, adding 20 variables. The binary *bynow* variable indicates whether the relationship is ongoing (1) or ended (0), capturing whether parties currently exchange information and resources. Duration is encoded as the number of years the connection lasts or lasted, converted to an ordinal scale: 0 (no connection), 1 (non-lasting, transactional), 2 (up to 4 years), 3 (5–10 years), 4 (11–20 years), 5 (over 20 years), and 6 (kinship/marriage, informal only). This distinguishes transactional connections (short-term, tactical exchanges)[6] from relational ones (long-term, strategic trust-based interactions) (Arifin, Hasan, Kabir, 2020; Hillman, Hitt, 1999) [6; 79]. From the behavioral perspective, both current status and duration control for the relevance and reliability of the bank-state relationship behind a connection (Wei, Jia, Bonardi, 2023, p. 1879) [44]. We do not use years since the end of the connection, as this largely duplicates the current status and does not capture relationship maturity.

Regardless of the identification method, an important dimension of heterogeneity is the connection's origin: whether banks establish connections bottom-up in their favor, or politicians establish them top-down in their own interests. To consider this, we encode a "revolving doors" variable (*revolv*) for each of the 10 types (adding 10 variables, totaling 40). *Revolv*, depicting the moment of connection establishment, equals 0 if the connection existed before the banker's affiliation with the bank (joining management or acquiring equity), and 1 if initiated after affiliation. This variable captures the actor whose interests the connected banker represents. A value of 1 suggests that the bank gained official attention (e.g., receiving a state award) or

[5] Federal Financial Markets Service operated in 2004–2013.

[6] For example, consider a presidential decree awarding a banker, a one-time business meeting with a government official, or a large contract that a businessman received from a government agency on preferential terms.

the banker established connections to improve bank performance (e.g., through parliamentary elections, as Szakonyi (2018) [15] shows). A value of 0 implies that the banker arrived with pre-existing connections, potentially carrying obligations from prior relationships that may provoke agency problems.

Zhang, Marquis, and Qiao (2016) [22] similarly distinguished "ascribed" connections (government positions held before entering business) from "achieved" ones (parliamentary mandates acquired after taking a business position) for Chinese private firms. They found that ascribed connections buffer firms from pressure to donate to government-affiliated NGOs, while achieved ones impose obligations resulting from the state's interest in co-opting business leaders. Our argument differs, though it remains untested. First, connections established before joining a firm carry the imprint of previous relationships whose trust-based nature inevitably includes mutual obligations – not just benefits – as social exchange or social embeddedness theories argue. Second, formal political experience may create "role persistence" (Schein, 1971; Van Maanen, Schein, 1977) [80; 81], where ex-officials remain guided by their former colleagues' interests. Third, past connections may have had nothing to do with the current business, introducing uncertainty through agency problems. This fallacy often stems from the assumption that firms hire ex-politicians – like revolving-door lobbyists (Blanes i Vidal, Draca, Fons-Rosen, 2012) [82] – to reduce policy uncertainty, especially in sectors most dependent on government resources (Hillman, 2005; Okhmatovskiy, 2010, p. 1027; Goldman, Rocholl, So, 2009; Palmer, Schneer, 2016) [1; 13; 47; 79]. However, this may not hold in contexts with limited institutions, such as Russia or China: officials may place ex-colleagues in firms to gain influence over businesses, complementing the standard bottom-up recruitment logic. Moreover, since Zhang, Marquis, and Qiao considered only ascribed governmental and achieved parliamentary connections [22], the effects they uncovered might be driven not by the timing of establishment but by the institutional origins of those connections.

Dealing with endogeneity of political connections

Although encoding the time a political connection is established gives some indication of how much a bank may intend to use the relationship to facilitate its own performance, we also use this variable to address endogeneity. When a connection is established after a banker's affiliation with the bank, it is necessarily associated with the bank's current activities. We cannot be sure whether the political connection influenced the bank's performance or vice versa, regardless of whether the connection is bottom-up or top-down. Researchers face the endogeneity problem when both the connection proxy and performance variables are driven by some unobservable factor. For example, a bank expecting a deterioration in performance may purposefully establish ties with an official developing a subsidy program; conversely, the government may seek a well-performing bank to implement a new lending stimulation program. In both cases, the expected effect of connections is preceded by accounting for financial indicators, so we cannot guarantee causality.

Researchers often use quasi-experimental methods, including matching and instrumental variables (e.g., Arifin, Hasan, Kabir, 2020; Wang et al., 2019; Boubakri, Cosset, Saffar, 2008; Han, Zhang, 2018; Trifonov, 2021; Farag, Dickinson, 2020; Halford, Li, 2020) [6; 11; 17–19; 34; 83]. However, finding theoretically sound instruments is difficult, and these methods do not elucidate the nature of banker-official interactions. We take a different approach. Under certain circumstances, the appearance of politically connected owners or managers may not aim to influence bank activities through their connections – particularly regarding the timing of joining the bank. As Preuss and Königsgruber (2021, p. 21) [76] argue, not all political connections are "active" in nature, e.g., established for specific tasks, as in the examples above. "Passive" connections, which emerge without this objective in mind, e.g., arising from geographical proximity, may affect business activities exogenously.

Since our identification approach does not use geographical proximity, we encode the circumstances of acquiring connections with three binary variables that help identify exogenous connections – those independent of the initial desire to influence the business. First, *founder* equals 1 if the banker's start year coincides with the bank's registration year. Second, *parentcomp* distinguishes the bankers affiliated with the bank's parent organization before joining. We define a parent organization based on two criteria: a) the bank is not the primary asset of the parent organization[7], and b) the parent organization either holds >1% of the bank's equity or is owned by one of the bank's direct beneficiaries. This includes larger parent banks and government property agencies. Third, *family* identifies bankers who joined when their relative was already among the managers or owners. These variables are constant at the banker level. A value of 1 for any of these three variables suggests that the person's entry into the bank's management or ownership was not related to the political connections they held at that time.

These criteria help isolate likely exogenous connections

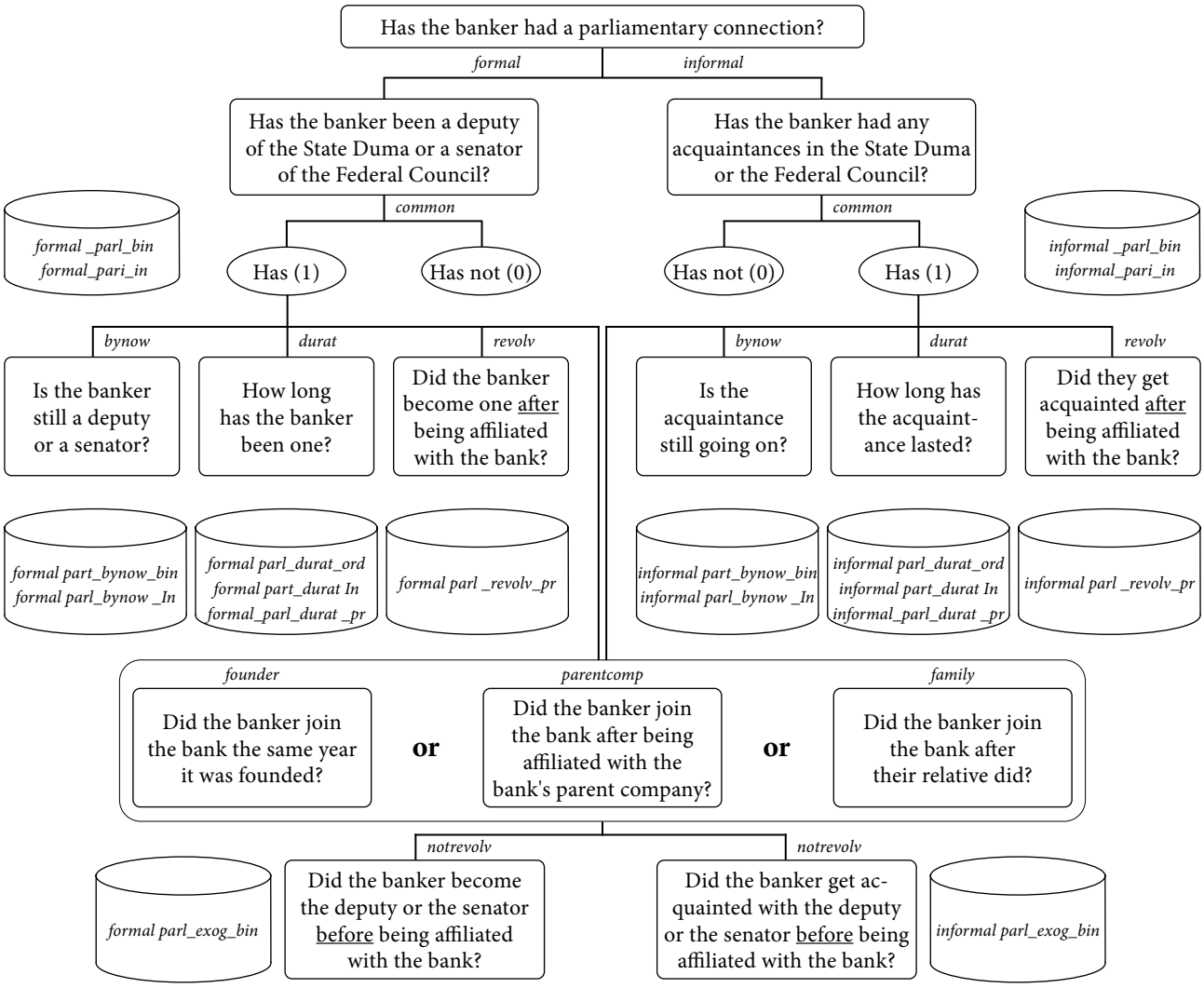
We use these variables in combination with *notrevolv* (connection established before joining the bank, opposite of *revolv*) to encode exogenous connections (*exog*). For each i banker of j bank in t year: $exog_{ijt} = notrevolv_{ijt} \times (founder_{ij} = 1 | parentcomp_{ij} = 1 | family_{ij} = 1)$. A political connection is considered exogenous if established before the banker founded the bank, or joined while already affiliated with the parent organization, or joined as a relative of an existing banker from this bank.

[7] This excludes entities such as offshore companies used to hold the banker's stake or holding firms whose main purpose is owning the bank.

that could serve as instruments in regression analysis. However, limitations remain. First, some of the connections acquired before joining but not meeting our criteria may also be exogenous (false negatives), while our method likely excludes cases where former officials are appointed in the state's interest (false positives). Thus, our algorithm is conservative: low Type I error (excluding endogenous connections), high Type II error (missing exogenous ones). Second, in systems with pervasive informal business-government relations and weak formal institutions, political connections may be deeply rooted in the economic system itself, e.g., childhood friends whose relationships shaped privatization outcomes. Here, endogeneity is related to the nature of property rights and firm origins rather than a company's current activities. Also, as certain studies argue, the role of political connections is linked to property rights problems (Chen et al., 2011, p. 237; Frye, 2017; Xin, Pearce, 1996; Earle et al., 2021) [24; 39; 55; 56]. While social network analysis can identify connections with political figures vital for a group of businesses (Bussolo, Commander, Poupakis, 2023) [35], quantitative methods alone cannot fully capture how ties of this kind interact with governance and activities. Nevertheless, we can confidently identify connections possessed only by bankers who established them before joining the bank or before its foundation. The proposed variables capture this.

In total, for each banker we encode 43 variables: 5 types (*parliamentary*, *regulatory*, *governmental*, *corporate*, *regional*) × 2 approaches (formal, informal) × 4 variables (*common*, *bynow*, *durat*, *revolv*) + *founder* + *parentcomp* + *family*. Figure 1 illustrates the encoding algorithm. Based on this, we construct 10 additional banker-level variables of exogenous political connections: 5 types × 2 approaches × 1 variable (*exog*)[8].

Figure 1. The general algorithm for identifying a banker's political connection (an example of the parliamentary type of political connection)



Note: The final bank-level variables of parliamentary connections after aggregation (see the next section) are presented in cylinders.

[8] We do not account for 10 *notrevolv* variables since they are applied only as a step to obtain *exog* variables.

Operationalization of political connections and other institutional features

After identifying political connections for each banker, we aggregate the data to bank-year observations. Following Farag, Dickinson (2020) [34], Houston et al. (2014) [5], and Halford, Li (2020) [83], we operationalize connections in two ways: binary and quantitative.

Binary encoding. For *common* connections and their current status, a bank receives 1 for a year if at least one banker was assigned 1 for the corresponding variable of that connection type. We do not use revolving doors variables in binary form, as they are meaningful only in relation to *notrevolv* connections. For exogenous connections, we apply a conservative rule: a bank gets 1 for a given type only if all its connections of that type are exogenous. For example, if a bank has two directors with informal parliamentary connections identified as exogenous, it receives 1 for exogenous parliamentary informal connections only if no other bankers in the bank have parliamentary informal connections not identified as exogenous.

Quantitative encoding. Assuming that a larger number of connected bankers reflects greater ability to interact with officials, for each of the 10 connection types we use: 1) for *common* connections, the natural logarithm of the number of politically connected bankers; 2) for *bynow* connections, the natural logarithm of the number of bankers with ongoing connections; 3) for revolving doors, the proportion of bankers who acquired a connection after joining the bank, relative to all bankers with the *common* connection of that type. This captures the balance of interests behind connections. We do not construct a similar proportion for exogenous connections: if any connection of a given type is endogenous, we cannot guarantee that an effect is not driven by it.

Duration variables are transformed in three ways: 1) maximum ordinal value (0–6) among bankers with *common* connections of a given type; 2) mean of the natural logarithm of connection duration (in years) across bankers with that connection type, capturing average quality; 3) ratio of bankers with relational (lasting) connections to all bankers with that connection type, indicating the prevalence of trust-based versus transactional ties. Depending on research purposes, any of these measures may be appropriate.

Other institutional features. For each bank year, we aggregate the parent organization variable (*Parentcomp*) as the proportion of bankers with *parentcomp* = 1. It captures concentrated corporate control structure, which may divert the bank from normal activities in the interests of its (usually non-banking) holding company. It also signals greater exposure to rent-seeking by controlling beneficiaries, as such costs are lower in more homogeneous governance structures (Arifin, Hasan, Kabir, 2020, p. 13; Chen et al., 2011) [6; 24].

We also include ownership form and size. Control of a bank through state ownership – directly or via state-owned companies (Vernikov, 2014, p. 5–6) [42] – may indicate political influence on bank activities (Sapienza, 2004; Fungáčová, Herrala, Weill, 2013; Boateng, Liu, Brahma, 2019) [51; 52; 73]. Following Preuss and Königsgruber (2021) [76], some treat state ownership as a proxy for political connections. However, we argue that, since ownership captures formal subordination rather than relational ties and cannot provide the same depth of insight into business-state relationships as connections through directors can (Frye, Iwasaki, 2011; Grosman, Wright, Okhmatovskiy, 2016) [20; 54]. State ownership also implies other institutional features: higher market power, control over smaller banks, participation in infrastructure projects, presence in strategically important markets, employment of officials' relatives, and more (Vernikov, 2014) [42]. We use four binary ownership variables: majority state ownership (>50%, *SOB*), any state ownership (>0%, *SOSh*), majority foreign ownership (*ForB*), and any foreign ownership (*ForSh*)[9].

Bank size reflects a bank's structural power, resulting from politicians' unwillingness to harm systemically important businesses through their decisions (Fairfield, 2015, p. 414) [84]. The source of a bank's structural power is traditionally considered to be its unique ability to saturate the economy with money supply, provide financial intermediation between individuals and businesses, and, in recent years, fulfill a geo-economic role for its state of residence (Dafe et al., 2022) [85]. We use the natural logarithm of net assets (*lnNA*) as a proxy for bank size.

Finally, we include a binary variable for banks usually founded in the second half of 1990 and early 1991 on the basis of one of the Soviet "spetsbanks" (*Spets*). This origin typically reflects that the founders of new commercial banks, or those close to them, had influence and connections in the regional structures of the USSR State Bank, e.g., were former employees of Soviet spetsbanks, local officials and deputies close to them, or "red directors" – the heads of Soviet enterprises, whose fragments often became the foundations of new commercial banks. Berkowitz, Hoekstra, and Schoors (2014) [40] showed these banks were the most politically connected in the mid-1990s and very active in lending to state-owned enterprises. However, later data suggest that they no longer exhibit distinct political lending patterns (Fungáčová et al., 2023, p. 907–911) [43].

All bank-level variables are summarized in Figure A.1 and Table A.2, available in the Appendix. For brevity, the table illustrates only formal parliamentary (*parl*) connections; the same formulas apply to all types – regulatory (*regul*), governmental (*gov*), corporate (*corp*), regional (*region*), and both identification approaches – direct (formal), and indirect (informal).

Descriptive analysis of political connections

Despite the fact that out of 2,598 coded bankers from 115 banks only 22% had at least one political connection, the distribution of politically connected bankers by bank

[9] Foreign ownership (majority or partial) refers to shareholders who are foreign nationals or corporations, not offshore-registered domestic capital.

confirms that political connections are widespread in the Russian banking sector. Over the seven years from 2015 to 2021, 102 out of 115 banks (89%) had at least one banker with a political connection.

The distribution of banks by the five types of connections in direct and indirect encodings, by ownership, and by spetsbank origin is presented in Table 1. The rarest connections are those with regulatory authorities, work experience in the federal parliament as a deputy or senator, or in federal ministries and departments. Informal acquaintances with regional authorities, federal executive bodies, or state-owned companies (SOEs) occur in nearly half of all banks. On average, only seven banks were fully state-owned, with eight more having minority state stakes. Foreign ownership is more common. Twentynine banks in our sample were founded or developed from spetsbanks.

Table 1. The number of banks with at least one common connection of each type by year

Year	Any connection	Formal parliamentary	Informal parliamentary	Formal regulatory	Informal regulatory	Formal governmental	Informal governmental	Formal corporate	Informal corporate	Formal regional	Informal regional	Majority state ownership	Partial state ownership	Maj. foreign ownership	Part. foreign ownership	Spetsbank
2015	99	13	41	16	20	11	56	35	55	43	61	7	14	10	29	29
2016	102	13	41	17	23	12	57	36	54	44	62	8	16	10	28	29
2017	102	13	43	14	24	11	56	35	55	41	62	7	15	10	28	29
2018	102	12	44	17	22	10	57	35	55	40	62	7	15	10	26	29
2019	101	12	44	18	21	10	58	35	54	39	61	7	15	11	24	29
2020	103	12	44	19	20	12	59	38	54	40	63	9	17	11	24	29
2021	102	13	43	19	19	13	58	39	53	38	59	9	17	11	24	29

Table 2 reports, for each connection type, the average proportion of bankers with ongoing connections (*bynow*), revolving doors connections (*revolv*), and relational connections (*durat*), calculated relative to all bankers having that *common* connection type. For all five types except regional, ongoing connections are more frequent among bankers with informal acquaintances than among those with job experience in state bodies or SOEs. Bankers rarely simultaneously hold bank positions and political office, though current employment in SOEs exceeds past employment.

Table 2. The average proportion of ongoing, revolving doors, and relational political connections by bank, median values by year

Type of political connection	Parliamentary	Regulatory	Governmental	Corporate	Regional
Formal ongoing	0.250	0.043	0.246	0.568	0.372
Informal ongoing	0.547	0.515	0.394	0.667	0.307
Formal revolving doors	0.385	0.000	0.095	0.310	0.253
Informal revolving doors	0.512	0.455	0.444	0.488	0.484
Formal relational	1.000	1.000	1.000	1.000	1.000
Informal relational	0.872	0.909	0.656	0.880	0.540

Note: The mean proportions in each cell of the table are calculated with respect to the maximum number of banks from the sample functioning without any regulation restrictions (111–113 banks) for each of the seven years, and then their median values by year are taken.

Revolving doors patterns are similar: for most connection types except acquaintances in the federal parliament, bankers typically established connections before joining the bank. Informal connections, however, are more often formed post-joining. As the proportions demonstrate, these variables capture meaningful variation beyond the *common* connection indicators. All formal connections are relational by definition (work experience implies relationship building). Among informal ties, transactional connections (e.g., meetings, awards, contracts) are most common with regional authorities – half of regionally connected banks lack long-term connections. Transactional connections also appear in one-third of acquaintances with federal executive bodies. Informal connections with parliament, regulators, and SOEs are overwhelmingly relational (business partnerships, advisory council membership, friendships).

Table 3 shows maximum connection durations as of 2021. Long-term formal ties (>10 years) are more common with state-owned companies and regional authorities; few banks have people with work experience in federal bodies. Informal long-term connections are more frequent with the federal government and SOEs, slightly less so with parliament. Long-lasting regulatory ties are rare in both formal and informal forms.

Table 3. Distribution of the number of banks by the maximum duration of connections in 2021

Type of political connection	Duration, years	Parliamentary	Regulatory	Governmental	Corporate	Regional
Formal duration	No connection	100	94	100	74	75
	Up to 4	5	10	2	7	3
	5–10	6	6	6	15	13
	11–20	2	3	4	13	18
	20 or more	0	0	1	4	4
Informal duration	No connection	70	94	55	60	54
	Non-lasting	6	1	16	8	19
	Up to 4	5	2	5	3	1
	5–10	11	6	10	10	10
	11–20	12	5	13	20	6
	20 or more	2	5	8	9	8
	Kinship	7	0	6	3	15

Note: For each connection type in each cell, the number out of 113 banks from the sample in 2021 is computed.

In Table 4, we report median yearly values for exogenous connections (those unlikely to be performance-driven), since between-year variation is low. Our exogenous connection measures are conservative: they capture only connections meeting *founder*, *parentcomp*, or *family* criteria, and may miss some truly exogenous ties but ensuring those identified are reliable. Consequently, few banks have exogenous connections of any type.

Table 4. The number of banks with the exogenous political connections, median by year

Type of political connection	Parliamentary	Regulatory	Governmental	Corporate	Regional
Formal exogenous	2	3	1	6	8
Informal exogenous	9	5	11	14	9

Note: For each connection type in each cell, the number out of the maximum number of banks from the sample functioning without any regulation restrictions (111–113 banks) for each of the seven years is computed, and then their median values by year are taken.

Table 5 provides descriptive statistics for the log number of connected bankers per bank-year. Banks have the most politically connected owners, directors, and CEOs in informal regional and governmental categories. Over 75% of banks have no bankers with federal political experience. For all other types except regulatory, at least one-quarter of banks have at least one connected representative. Distributions of parent-organization affiliation and size (log net assets) are near-normal but right-skewed, indicating a subset of banks more dependent on parent businesses and noticeably larger.

Table 5. Descriptive statistics of quantitative political connection variables

	N	Mean	Std	Min	25%	50%	75%	Max
Formal_parl_ln	784	0.082	0.234	0.000	0.000	0.000	0.000	1.386
Informal_parl_ln	784	0.329	0.446	0.000	0.000	0.000	0.693	1.946
Formal_regul_ln	784	0.118	0.291	0.000	0.000	0.000	0.000	1.946
Informal_regul_ln	784	0.167	0.362	0.000	0.000	0.000	0.000	1.792
Formal_gov_ln	784	0.115	0.357	0.000	0.000	0.000	0.000	2.197
Informal_gov_ln	784	0.477	0.535	0.000	0.000	0.693	0.693	2.303
Formal_corp_ln	784	0.373	0.610	0.000	0.000	0.000	0.693	2.639
Informal_corp_ln	784	0.472	0.548	0.000	0.000	0.000	0.693	2.303
Formal_region_ln	784	0.366	0.537	0.000	0.000	0.000	0.693	2.197
Informal_region_ln	784	0.568	0.594	0.000	0.000	0.693	1.099	2.565
Parentcomp	784	0.296	0.225	0.000	0.116	0.250	0.467	0.846
lnNA	784	17.031	2.072	13.239	15.308	16.848	18.489	23.595

Bank behavior under different political connections

Next, we apply t-tests to illustrate the prospects of distinguishing different types of political connections in analyzing bank-state relationships. Table 6 presents the differences in banks' financial indicators, size (*lnNA*), and board linkage to the parent business (*Parentcomp*), depending on (1) the presence of *common* political connections (five types, formal and informal) and (2) above-median shares of revolving-doors connections (established after joining the bank) among connected banks. We focus on revolving-door variables given their underutilized research potential. Financial ratios include returns on assets (*ROA*), overdue loans (*SOL*), capital adequacy (*E_A*), corporate loans to assets (*LNA*), retail loans to assets (*RLA*), and individuals' deposits to assets (*RDA*).

Banks with formal connections to federal government, SOEs, and regional authorities share similar regularities: no significant differences in efficiency or credit risk, but capital adequacy is up to one-third standard deviation (SD) lower. Among the three banks with governmental connections established during their banking career[10] (systemically important VTB, Rosselkhozbank, Sovcombank), capital adequacy is another half-SD lower ($p < 0.001$). Only banks with these three formal connection types have higher corporate loan shares ($p < 0.001$). The 24 banks with revolving doors corporate connections lend even more to the economy ($p < 0.01$) but rely less on retail deposits ($p < 0.01$). Conversely, 19 banks with revolving doors formal regional connections have half-SD lower corporate lending ($p < 0.001$) than other regionally connected banks. Here, we observe not an amplification of the pattern seen with *common* connections, but the opposite one. This becomes clearer when three empirical facts are considered: first, these banks with revolving-doors bankers are more tied to parent businesses via governance structures ($p < 0.001$); second, they show slightly higher efficiency ($p < 0.05$); third, unlike these banks, those with directors appointed from regional or municipal authorities (i.e., non-revolving doors) tend to be owned by those very bodies and lend more actively to the economy.

[10] For four types of formal connections (all except corporate), the median proportion of bankers who joined state agencies after becoming affiliated with the bank is zero. Thus, a value above the median effectively means the bank has at least one such revolving doors connection. For formal corporate connections, the median proportion is also near zero, so apart from multiple zeros, only two non-zero observations fell into the below-median group.

If banks with more post-joining connections implement profitable market strategies, lower capital adequacy among those with federal government ties may indicate more aggressive, and hence riskier, credit policy, according to moral hazard logic. Lower corporate lending by banks whose bankers became regional deputies (the most common strategy) or held local office – often with more parent-business ties – may reflect a strategy of using the bank as a "money storage tank" for related businesses, potentially boosting efficiency. Also, lower retail deposit dependence among banks whose managers or owners later joined SOEs may signal their greater access to SOE funds.

Meanwhile, banks with these three types of formal connections differ in their retail strategies. Banks with formal governmental connections attract fewer retail deposits ($p < 0.01$); those tied to regional authorities attract more ($p < 0.001$) but lend less to households ($p < 0.001$). By contrast, banks with formal connections to SOEs lend more to households ($p < 0.001$).

Informal acquaintances in these three groups of state entities show different patterns. Banks with informal governmental ties do not differ from others in corporate lending but have lower retail lending ($p < 0.001$). Among those with above-median revolving doors informal governmental connections, corporate ($p < 0.05$) and retail ($p < 0.01$) lending are lower. On average, banks with informal governmental connections are a half-SD larger ($p < 0.001$, while significantly smaller than banks with similar but formal connections) and more parent-connected ($p < 0.01$), with lower profitability ($p < 0.05$) and capital adequacy ($p < 0.05$), but with no difference in overdue debt. However, the 35 banks with more post-joining governmental acquaintances show higher capital adequacy ($p < 0.05$) and lower credit risk ($p < 0.05$), consistent with the view that connections formed by current bankers better serve the bank's interests. The predominance of "old" federal acquaintances may indicate bankers' deeper embeddedness related to the property rights origins and greater obligations to the state, while post-joining informal governmental connections resemble the pattern seen with revolving doors formal regional connections. Thus, we assume that buffering from the state may arise via informal governmental or formal regional connections, but only if established during banking tenure.

Informal regional connections show no differences except lower credit risk ($p < 0.01$), and even onethird-SD lower for banks with more revolving doors ties ($p < 0.001$). Perhaps these differences are more likely the cause of such connections, as when local bank heads receive awards and recognition from the regional administration for their reliable or socially oriented banking activities, including a fairly conservative strategy that ensures the sustainability of the local economy. At the same time, in addition to awards, these often include partnerships, friendships, or kinship between bankers and representatives of regional or local authorities, and bankers' membership in public councils and chambers of the region. Formal regional connections lack this effect due to moral hazard stemming from direct policy access through bureaucratic positions.

Banks with acquaintances in SOE management – almost half-SD more parent-connected ($p < 0.001$) – and those with informal contacts with the government have lower capital adequacy ($p < 0.01$) and rely less on retail deposits ($p < 0.05$). However, banks with more postjoining corporate acquaintances in the public sector have higher capital adequacy ($p < 0.01$) and lower household lending ($p < 0.05$).

Parliamentary and regulatory connections merit special attention. Banks with formal or informal parliamentary ties differ little from others, except for attracting and lending fewer retail funds. Deputy- or senator-connected banks are riskier ($p < 0.01$) and less parent-dependent via owners and directors ($p < 0.001$). More variation emerges through the revolving doors status. The six banks whose bankers became federal MPs post-joining show one-third-SD higher profitability ($p < 0.05$) and almost half-SD lower overdue loans ($p < 0.01$) than their peers with non-revolving doors MPs as bankers[11]. The 28 banks with more post-joining informal parliamentary acquaintances have lower corporate lending ($p < 0.01$). These patterns echo those observed for informal governmental and formal regional post-joining connections, except that revolving doors parliamentary ties (both formal and informal) correlate with lower governance dependence on parent organizations ($p < 0.001$). Thus, revolving doors parliamentary, informal governmental, and formal regional connections may insulate banks from state pressure – manifest in lower lending, lower risk, and higher capital adequacy.

Banks with formal regulatory connections – all pre-joining[12] – exhibit higher credit risk ($p < 0.05$), lower capital ($p < 0.05$), lower profitability ($p < 0.1$), and fewer retail deposits ($p < 0.01$), in the absence of differences in the volume of lending to the economy and private citizens, suggesting that these ties reflect strategic choices by riskier banks. Informal regulatory connections also show higher credit risk ($p < 0.05$) and lower capital ($p < 0.001$), but more active retail lending ($p < 0.01$). However, the 12 banks with more post-joining informal regulatory connections lend less to businesses ($p < 0.1$) and households ($p < 0.05$) and have almost one SD lower credit risk ($p < 0.001$). Again, the revolving doors status reveals divergent behavior.

Overall, banks with different political connections exhibit distinct business models and financial outcomes, suggesting that connections serve different purposes or reflect different bank strategies. These preliminary findings warrant testing with more advanced econometric methods.

[11] Among the sixteen banks with a formal parliamentary connection in at least one year, the proportion of revolving-doors connections takes only values of zero or one: either all such connections were established before the banker joined the bank, or all were established afterwards by current bankers.

[12] In our sample, there are no bankers who worked at the Central Bank and later returned to their bank.

Table 6. Comparisons of banks' financial ratios on the presence of *common* political connections and the median of revolving doors connection proportions

Type of political connection	ΔROA (std = 0.012)		ΔSOL (std = 0.042)		ΔE_A (std = 0.088)		ΔLNA (std = 0.195)		ΔRLA (std = 0.098)		ΔRDA (std = 0.109)		ΔlnNA (std = 2.072)		ΔParentcomp (std = 0.225)	
	Common	Revolv	Common	Revolv	Common	Revolv	Common	Revolv	Common	Revolv	Common	Revolv	Common	Revolv	Common	Revolv
Formal parliamentary	−0.001	0.004*	0.011**	−0.018**	0.018	−0.012	0.021	0.032	−0.033***	−0.001	−0.059***	0.037’	0.014	−1.366**	0.017	−0.158***
Informal parliamentary	−0.000	0.001	0.002	−0.000	0.005	0.001	−0.023	−0.060**	−0.025***	−0.022*	−0.024**	−0.038**	0.604***	0.873**	−0.075***	−0.085***
Formal regulatory	−0.002’		0.010*		−0.018*		0.001		0.013		−0.032**		1.203***		0.035	
Informal regulatory	−0.001	0.003	0.010*	−0.040***	−0.027***	0.009	0.023	−0.070’	0.037**	−0.053*	−0.013	0.025	1.938***	0.005	−0.020	−0.094**
Formal governmental	−0.000	0.001	0.005	−0.010	−0.030***	−0.047***	0.079***	−0.066	−0.003	−0.018	−0.041**	−0.038’	2.345***	3.010***	−0.066*	−0.139**
Informal governmental	−0.002*	−0.000	−0.002	−0.009*	−0.015*	0.023*	−0.021	−0.047*	−0.023***	−0.028**	0.003	0.004	0.996***	−0.329	0.051**	0.036
Formal corporate	0.000	0.002	0.003	−0.003	−0.027***	0.002	0.053***	0.066**	0.036***	0.016	−0.015’	-0.042**	1.498***	1.225***	0.072***	−0.030
Informal corporate	−0.001	0.000	−0.003	−0.004	−0.018**	0.030**	−0.014	−0.036	−0.007	−0.028*	−0.017*	-0.001	1.148***	−0.399’	0.107***	−0.038
Formal regional	−0.001	0.002*	−0.002	0.001	−0.014*	0.007	0.055***	−0.097***	−0.021***	−0.002	0.042***	0.018	−0.787***	−0.714***	−0.043**	0.083***
Informal regional	−0.000	0.002	−0.007**	−0.013***	−0.003	0.004	−0.000	−0.007	−0.007	−0.013	0.070***	0.006	−1.160***	1.054***	−0.074***	−0.039’

Note: The table reports t-test comparisons of mean financial ratios for banks with a given type of common political connection versus other banks (columns “common”), and between two subgroups of banks sharing that connection type: (1) those where the proportion of bankers who established the connection after joining the bank exceeds the median for all banks with that connection type, and (2) those where this proportion is below the median (“revolv” columns). Empty cells for formal regulatory revolving-doors connections reflect the absence of such cases in the sample. Levene's test was used to assess homogeneity of variances; when the test indicated unequal variances ($p<0.05$), we applied Welch's t-test. A positive delta indicates that the mean for the group of interest exceeds that of the comparison group. Unbiased standard deviations for each ratio, calculated for the full sample (N = 780), are shown in parentheses. ’ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Patterns in political connections: cluster analysis

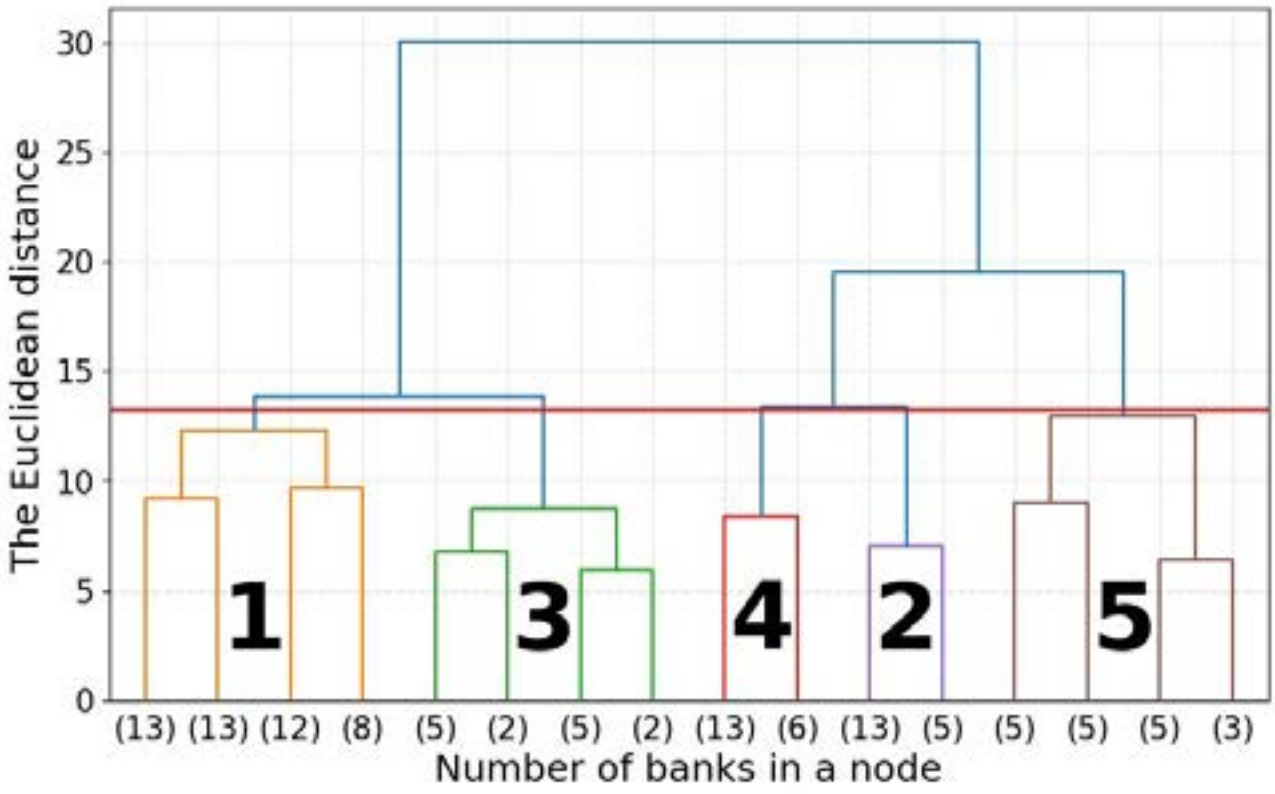
The wide variety of political connection types makes it challenging to incorporate them directly into the analysis of bank behavior and its financial outcomes, especially since individual banks often combine multiple connections with potentially conflicting effects. In this section, we move beyond isolated institutional features (connections, size, dependence on another business) and identify broader patterns across groups of banks using hierarchical clustering.

For clustering, we employed 40 quantitative connection variables (log number of bankers with *common* and ongoing connections, proportion of revolving doors connections, and average log duration for each of 10 connection types), along with four ownership-control variables, parent-organization dependence, and bank size. We excluded the spetsbank variable due to its limited explanatory power for banks' current positioning and, in our opinion, vague institutional features behind it. To reduce dimensionality, we applied principal component analysis (PCA) to the 40 connection variables, extracting two principal components per connection type (10 components total), each derived from eight correlated variables: *common*, *bynow*, *revolv*, *durat* for direct (experience) and indirect (acquaintances) identification. PCA details are provided in the Appendix.

These 10 components, together with ownership, parent-organization, and size variables, were used for hierarchical clustering. To obtain groups of banks with minimal variance within each group, we applied Ward's method for linking observations to clusters (Ward, 1963) [86]. Figure 2 presents the dendrogram. We selected a five-cluster solution (distance threshold = 13) as the most interpretable. A higher threshold (14–15) would yield only three clusters driven primarily by bank size. The subsequent division into five clusters – rather than three – is shaped by variation in political connections, ownership forms, and parent-group linkages. As shown below, clusters of comparable size (e.g., clusters 1 and 3, or 2 and 4) nonetheless differ in their connection profiles, and these differences correspond to significant variation in financial performance and business models. A lower threshold (≤12) would produce seven clusters, splitting clusters 1 and 5 into smaller, less coherent groups without adding interpretive value.

The dendrogram structure reveals distinct grouping patterns: clusters 1 and 3 are separated by the same distance (≈14) as clusters 2 and 4. Cluster 5 stands further apart, with a distance of about 20 from the combined clusters 2 and 4. The most pronounced separation (distance ≈30) is between the union of clusters 1 and 3 (predominantly small and medium-sized banks) and the aggregate of clusters 2, 4, and 5.

Figure 2. Hierarchical clustering of banks



Note: The red horizontal line marks the distance threshold (13) chosen for the final clustering solution. Cluster nodes are colored according to group membership, with numbers assigned accordingly. Cluster numbers reflect an ordering from least influential cluster 1 (fewer connections, smaller size) to most influential cluster 5 (more connections, greater size).

Table 7. The proportion of banks with at least one common political connection of the appropriate type by cluster

Cluster	Cluster name	Number of banks	Type of connection	Proportion of banks from cluster with at least one connection of the type					Median number of one bank's connections of the type					Maj. state ownership	Part. state ownership	Maj. foreign ownership	Part. foreign ownership	Parent organization	Size	Spetsbank
				Parliamentary	Regulatory	Governmental	Corporate	Regional	Parliamentary	Regulatory	Governmental	Corporate	Regional							
1	Small regionals	46	Form	0.04	0.09	0.07	0.17	**0.57**	0	0	0	0	1	0.04	0.11	0.01	0.11	0.28	15.5	0.37
			Infor	0.15	0.11	0.41	0.35	**0.85**	0	0	0	0	1							
2	Unconnected outsiders	18	Form	0	0.17	0.11	0.22	0	0	0	0	0	0	0.05	0.05	0.45	**0.50**	0.35	18.6	0.11
			Infor	0.17	0.11	0.22	0.06	0.11	0	0	0	0	0							
3	Elected from regions	14	Form	**0.50**	0.07	0.07	0.14	**0.64**	0.5	0	0	0	1	0.00	0.07	0.00	0.07	0.22	15.7	0.14
			Infor	**1**	0	0.43	0.21	**0.57**	1	0	0	0	1							
4	Influential corporators	19	Form	0.05	0.16	0	**0.58**	0	0	0	0	1	0	0.02	0.06	0.11	0.28	0.35	17.6	0.05
			Infor	0.37	0.37	**0.68**	**1**	0.11	0	0	1	1.5	0							
5	State-held federals	18	Form	0.11	0.39	0.33	**0.61**	0.28	0	0	0	2.5	0	0.28	0.47	0.00	0.38	0.29	20.2	0.39
			Infor	**0.67**	0.44	**0.72**	**0.83**	**0.61**	1	1	2	2	1							

Note: Proportions ≥ 0.5 are in bold.

Next, we present the grouping of banks by cluster. Table 7 characterizes the clusters by the proportion of banks with particular connections, median number of connected bankers, ownership forms, parent-organization ties, size, and spetsbank origin. Table 8 reports t-test comparisons of financial ratios across clusters. A detailed description of each cluster, including bank examples and significant differences in business models and financial performance, is provided below.

Table 8. Financial ratios differences between cluster and other banks based on t-tests

Cluster	ΔROA (std = 0.012)	ΔSOL (std = 0.042)	ΔE_A (std = 0.088)	ΔLNA (std = 0.195)	ΔRLA (std = 0.098)	ΔRDA (std = 0.109)
Cluster 1	–0.001	–0.010***	0.035***	–0.010	–0.022***	0.067***
Cluster 2	0.003*	0.005	–0.014*	–0.061**	0.017	–0.041***
Cluster 3	–0.002	0.005	0.033**	0.011	–0.019**	–0.009
Cluster 4	0.003**	0.002	–0.021***	0.030	0.032**	–0.016
Cluster 5	–0.004***	0.007*	–0.061***	0.043*	0.006	–0.063***

Note: The table reports t-tests comparing mean financial ratios for each cluster against banks outside that cluster. Levene's test was used to assess homogeneity of variances; when the test indicated unequal variances ($p < 0.05$), we applied Welch's t-test. A positive delta indicates that the cluster mean exceeds that of banks outside the cluster. Unbiased standard deviations for each ratio, calculated for the full sample (N = 780), are shown in parentheses. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Cluster 1. "Small Regionals" (46 banks) is the largest group, comprising small and medium-sized banks, occasionally with state or foreign ownership. Political connections are predominantly regional: 85% have at least one representative linked to regional or local authorities, and 37% originated from Soviet spetsbanks. These banks actively attract retail deposits ($p < 0.001$) but lend slightly less to households ($p < 0.001$). Their corporate lending is indistinguishable from other banks, partly because 14 of the 19 banks with above-median formal regional revolvingdoors connections, i.e., banks that lend significantly less to the economy, fall into this cluster. Credit risk is lower ($p < 0.001$), and capital adequacy is higher ($p < 0.001$). The latter pattern is not evident when examining regional connections alone, suggesting markedly distinct behavior among small regional banks.

Cluster 2. "Unconnected Outsiders" (18 banks) is a group of large or medium-sized banks, half of which are foreign-owned. They have virtually no significant political connections but maintain strong ties to parent (usually nonfinancial) businesses: on average, 35% of beneficiaries or managers work in or own the parent company, for which the bank is not a core asset. These banks show slightly higher efficiency ($p < 0.05$), lower capital adequacy ($p < 0.05$), significantly less reliance on retail deposits ($p < 0.001$), and less active corporate lending ($p < 0.01$).

Cluster 3. "Elected from Regions" (14 banks) consists of banks with acquaintances in the federal parliament; in half of these banks, directors or owners are former or current deputies or senators. Regional connections are also widespread. The banks are mostly small or medium-sized, without state or foreign ownership, and have minimal ties to larger businesses through ownership or management experience. Financially, these banks are less engaged in retail lending ($p < 0.01$) and maintain higher capital buffers ($p < 0.01$). Notably, five of the six banks whose bankers became federal deputies postjoining fall into this cluster; these five exhibit significantly better profitability and lower credit risk than banks where former deputies or senators joined the banking business after their term. While these differences are not significant for the full cluster, 12 of the 14 banks have abovemedian revolving doors connections of various types – informal parliamentary (seven banks), informal governmental (four), informal corporate (three), and formal regional (three) – suggesting potential insulation from state interference.

Cluster 4. "Influential Corporators" (19 banks) is a group of large and medium-sized banks, some with foreign ownership. They maintain extensive federal connections, particularly with stateowned enterprises (SOEs), both informal and through work experience. Half have multiple directors or CEOs with SOE contacts, often combined with strong parentorganization ties. These banks are onethird SD more active in retail lending ($p < 0.01$) and have lower capital adequacy ($p < 0.001$). Unlike Cluster 3, they exhibit multiple connection types simultaneously, with informal SOE access as a common thread, and show higher profitability ($p < 0.01$).

Cluster 5. "State-Held Federals" (18 banks) comprises the largest federal banks, state or foreign owned, with political connections of all types. Over half have two or more directors connected to the Russian government or SOEs. Although the spetsbank variable was not used in clustering, 39% of these banks originated from spetsbanks – the highest share among clusters. These banks lend more to the economy ($p < 0.05$), often in line with public policy

objectives, and rely less on retail deposits ($p < 0.001$). Consistent with the moral hazard logic, they have higher bad loan ratios ($p < 0.05$), twothirds SD lower capital adequacy ($p < 0.001$), and lower market efficiency ($p < 0.001$).

Conclusion

This paper introduces a manually collected dataset of 2,598 bankers from 115 Russian banks (2015–2021) and presents a detailed approach to identifying and operationalizing corporate political connections – applicable to banks or any other firms. Using mean comparisons and cluster analysis, we show that finer-grained measures of political connections reveal heterogeneity masked by conventional proxies, and that these measures, together with institutional characteristics, combine into distinct political patterns associated with bank governance and performance. We also address endogeneity concerns by proposing variables that capture connection exogeneity and discuss the inherent limitations of quantitative methods in this regard.

Our analysis confirms the deep political embeddedness of the Russian banking sector: every fifth banker and nine out of ten banks in our sample have at least one political connection. However, their distribution is uneven. Directors, board chairs, and owners are more frequently connected than managers or CEOs. Formal ties to federal bodies are rare (10–15% of banks), while connections to state-owned companies or regional authorities appear in 30–35% of banks. Informal ties – especially with regional bodies and federal executives – are more common, present in about half of all banks. Most formal connections (except corporate) are not ongoing or postjoining, whereas around half of informal ties are. Informal connections also tend to last longer than formal ones. Notably, only 14 banks have connections we were able to confidently classify as exogenous. Ttests reveal that different connection types correlate with institutional characteristics (e.g., size, parentcompany dependence) and can produce opposing effects on financial indicators depending on identification method (direct vs. indirect) and connection features (e.g., the moment of establishment). Cluster analysis reinforces these findings, identifying five groups of banks with distinct configurations of political connections, size, and ownership – from small regional banks with localized connections to large stateowned federal banks with comprehensive political networks. These clusters also exhibit statistically significant differences in financial outcomes and business models.

This research makes two main contributions. Theoretically, it confirms the widespread and heterogeneous nature of political connections in the Russian banking sector and deepens the understanding of how political interests permeate bank activities. Practically, it offers a system of variables capturing the origins, relevance, and maturity of political connections, creating additional variation that enables a more theoretically grounded estimation of how such connections affect bank behavior and financial performance.

For future applications, researchers can select from our metrics those best suited to their specific research question, accounting for institutional context and endogeneity. Consider two illustrations from banking studies. First, research on market discipline could use our measures to test whether depositors' sensitivity to bank risk varies not only by the presence of a connection but by its type – for instance, distinguishing parliamentary from executive ties (Disli, Schoors, Meir, 2013) [33]. Finer-grained features, such as the time of connection establishment, can further reveal the interests behind them, helping explain why depositors perceive certain connections as stronger signals of implicit state protection, or why connected banks attract more government deposits. Second, our variables can help disentangle banks' strategic responses to government interventions like subsidized lending programs. Banks with transactional ties to regulators may more easily opt out of riskexposed programs, while those with longstanding connections to local executive bodies may leverage them to signal compliance and secure participation. Additionally, exogenous connections – those established independently of a desire to influence bank outcomes – can serve as instruments to isolate causal effects and address endogeneity. In both cases, our framework enables researchers to align connection measures with the theorized mechanism, moving beyond the question of whether political connections matter to understanding which connections matter, when, and why. In essence, we offer a deeper lens through which political connections can be analyzed, explaining why prior studies often report heterogeneous or seemingly contradictory effects.

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Appendix

Procedure for encoding political connections of banks using direct and indirect approaches

To encode the political connections of each bank in the sample, we compiled a list of the bank's owners holding more than 1% of shares and disclosed by the bank, all members of the supervisory board, all members of the collegial executive body (including CEO), and the chief accountant who held their positions during at least one year between 2015 and 2021.

Then, for each person on the list, we recorded their job experience and positions held in government bodies, departments and companies that signaled the presence of a *common* connection. The examples of such bodies, and positions held in them, coded with a value of 1 for a person on the list, are given in Table A.1. The first source of information on such experience were quarterly reports and publications published by banks that disclosed the qualifications and work experience of bank executives for at least the past 5 years. In the absence of such information in the official bank publications, each person on the list was checked for the presence of any bibliographic information on the network using the Yandex search engine. The main sources of biographical and work-related information were pages about these persons on portals such as tadviser.ru, whoiswhopersona.info, wikipedia.org, as well as pages of federal and regional government bodies containing the biography of the person in question (if the person had work experience in these bodies).

If any facts corresponding to the presence of a formal political connection of one of the five types were discovered, this information was cross-checked using an additional search query. If the fact was confirmed by the biography from other open sources, a value of 1 was assigned for the person under the corresponding type of connection. The variables of the connection formation time (*revolv*), its current status (*bynow*) and duration (*durat*) were encoded in the same way according to the algorithm (see Figure 1).

Next, all persons from the list were checked for the presence of a political connection of one of the five types using an informal approach (indirect identification). A search query was made for each person in the Yandex search engine. The query, in addition to the person's name and the name of the bank, was also accompanied by marker words, such as "power", "government", "connections", and "corruption". In case of detection of any publications involving the person of interest, they were checked for information about their acquaintances or other indirect facts. Examples of such information, which support the person's connectedness, are also presented in Table A.1. Similarly, the variables *revolv*, *bynow* and *durat* were encoded for every person on the list.

Table A.1. Examples of information on the presence of political connections

Type of connection	Formal approach: work experience	Informal approach: acquaintance
Parliamentary (*parl*)	Deputy of the State Duma of the Federal Assembly of the Russian Federation in 2018–2021, Head of the Secretariat of the First Deputy Chairman of the State Duma of the Federal Assembly of the Russian Federation; Member of the Federation Council of the Federal Assembly of the Russian Federation from the Sakhalin Region in 2012–2017	Member of the Supreme Council of the United Russia party; son of a member of the Federation Council of the Federal Assembly of the Russian Federation from the Sverdlovsk Region in 2010–2021; partner of a member of the Federation Council of the Federal Assembly of the Russian Federation from the Kabardino-Balkarian Republic in 2014–2020; member of the Commission on Federal, Interregional and Regional Socio-Economic Policy under the Chairman of the Federation Council of the Russian Federation
Regulatory (*regul*)	Acting General Director at the Agency for Restructuring of Credit Organizations from 1998 to 2005; deputy head of the Main Directorate of the Central Bank of the Russian Federation for St. Petersburg	Has known E. Nabiullina since his time in the Government of the Russian Federation; chairman of the expert council on financial literacy at the Bank of Russia; advisor to the deputy chairman of the Central Bank of the Russian Federation in 2014–2017; under his leadership, the bank engaged in the rehabilitation of Investtorgbank
Government (*gov*)	Minister of Agriculture of the Russian Federation since 2018; Deputy Head of the Strategic Development Department of the Strategic Planning Department of the Ministry of Regional Development of the Russian Federation in 2013–2014; Assistant to the Plenipotentiary Representative of the President of the Russian Federation for the Northwestern Federal District	Direct relationship with the Presidential Executive Office during the implementation of the South Stream project; has headed the direction of technology business development at ASI since 2011, has been a member of the expert council under the Government of the Russian Federation; was awarded for his services in the field of economics and finance by the Decree of the President of the Russian Federation dated October 25, 2018
Corporate (*corp*)	Member of the Board of Directors of PJSC Rostelecom, JSC Mortgage Lending Agency, VEB.RF; since 2011, has been heading the direction of technology business development at ASI; member of the boards of directors of subsidiaries of PJSC Rosseti	Chairman of the Coordination Council of the RSPP in the Central Federal District; implemented the project to create a Nano-center commissioned by A. Chubais at RUSNANO; member of the Chamber of Commerce and Industry of the Russian Federation; in 2013–2015 companies associated with the bank director signed contracts with a subsidiary of Russian Railways for 37 billion rubles
Regional (*region*)	Head of the Office of the Mayor and the Government of Moscow in the rank of First Deputy Mayor of Moscow; deputy of the Kirov City Duma; Minister of Finance of the Government of the Chelyabinsk Region; vice-governor of St. Petersburg	Son of the mayor of Yekaterinburg; member of the public council under the Ministry of Economy of the Perm Region in 2014-17; former employee - Chairman of the Public Council under the Federal Tax Service of Russia for the Krasnodar Region; awarded the title of "honorary citizen" by the governor

As for additional indirect proof of connections, we resorted to scrolling through various regional media pages or portals of business information, publishing photographs, chronological notes, reports revealing company ownership structure, government procurement statistics, news about persons' participation in joint events, etc. The Integrum media archive was also used. As for the most publicly known personalities, major Russian businessmen and officials, search queries were formed specifically for the appropriate type of connections using marker words, e.g., "State Duma", "Central Bank", "Russian Union of Industrialists and Entrepreneurs".

The use of media materials, especially investigative ones, in the encoding procedure allowed for a more thorough analysis of scandalous incidents (e.g., a raid, an arrest, or a business dispute between a bank and a company) from the viewpoint of the interests of individual actors, including officials. This approach to the detection of connections, based on fact-checking of media materials regarding corporate or public interactions, was used by Gulnaz Sharafutdinova in her study of "crony capitalism" in Russia (2010, p. 17, 40) [37].

Figure A.1. All proposed variables for political connections and institutional features of banks

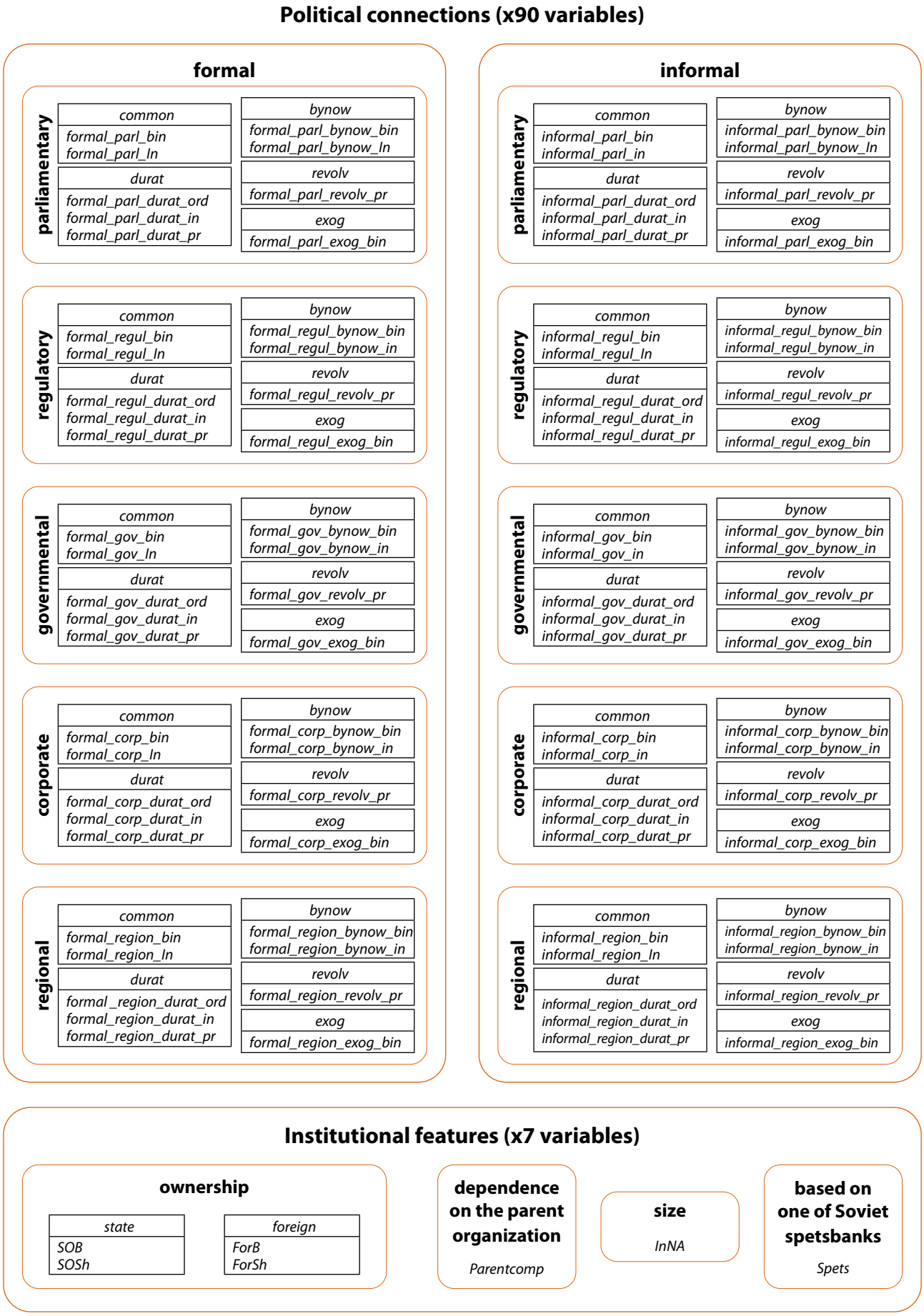

Table A.2. The variables of political connections and other institutional features: an example of a formal parliamentary political connection

Variable name	Computation	Notation
$Formal_parl_bin_{jt}$	$\max(common_{ijt})$ where $common_{ijt}$ – a binary variable, for *i* banker of *j* bank in *t* year	The binary variable denoting if there is at least one banker with a *common* formal parliamentary connection
$Formal_parl_bynow_bin_{jt}$	$\max(bynow_{ijt})$ where $bynow_{ijt}$ – a binary variable, for *i* banker of *j* bank in *t* year	The binary variable denoting if at least one banker currently maintains a formal parliamentary connection
$Formal_parl_exog_bin_{jt}$	$\begin{cases} 1 & \text{if } \max(exog_{ijt}) = 1 \text{ and } \sum(exog_{ijt}) = \sum(common_{ijt}) \\ 0 & \text{if } \max(exog_{ijt}) = 0 \text{ or } \sum(exog_{ijt}) < \sum(common_{ijt}) \end{cases}$ where $exog_{ijt}$ and $common_{ijt}$ – binary variables of the same connection type, for *i* banker of *j* bank in *t* year	The binary variable of the exogenous parliamentary connection in the direct identification approach (i.e., formal), denoting if there is at least one banker with such an exogenous connection and no bankers maintain an endogenous connection of the same type
$Formal_parl_ln_{jt}$	$\ln(\sum(common_{ijt}) + 1)$ where $common_{ijt}$ – a binary variable, for *i* banker of *j* bank in *t* year	The natural logarithm of the number of bankers with a *common* formal parliamentary connection
$Formal_parl_bynow_ln_{jt}$	$\ln(\sum(bynow_{ijt}) + 1)$ where $bynow_{ijt}$ – a binary variable, for *i* banker of *j* bank in *t* year	The natural logarithm of the number of bankers with a current formal connection of a parliamentary type
$Formal_parl_revolv_pr_{jt}$	$\frac{\sum(revolv_{ijt})}{\sum(common_{ijt})}$ where $revolv_{ijt}$ and $common_{ijt}$ – binary variables of the same connection type, for *i* banker of *j* bank in *t* year	The proportion of bankers with a formal parliamentary connection established after affiliation with the bank, of the total number of bankers with the same connection type
$Formal_parl_durat_ord_{jt}$	$\max(ordered(durat_{ijt}))$ where $durat_{ijt}$ – the number of years a connection has lasted for, and the function *ordered* converts it into values 0–6, for *i* banker of *j* bank in *t* year	The ordinal variable of the maximum number of years for which a formal parliamentary connection has lasted among all bankers with a lasting political connection of the same type

Variable name	Computation	Notation
$Formal_parl_durat_ln_{jt}$	$\frac{\sum(\ln(durat_{ijt}+1))}{\sum(common_{ijt})}$ where $durat_{ijt}$ and $common_{ijt}$ – variables of the same connection type, for *i* banker of *j* bank in *t* year	The mean natural logarithm of the number of years for which a formal parliamentary connection has lasted, taken with respect to the total number of bankers with the same connection type
$Formal_parl_durat_pr_{jt}$	$\frac{\sum(relational(durat_{ijt}))}{\sum(common_{ijt})}$ where $durat_{ijt}$ and $common_{ijt}$ – variables of the same connection type, and the function *relational* converts $durat_{ijt}$ into 0 for values 0–1 and into 1 for values 2–6, for *i* banker of *j* bank in *t* year	The proportion of bankers with a relational (lasting) political connection of a parliamentary type in the direct identification approach, of the total number of bankers with a political connection of the same type
$Parentcomp_{jt}$	$\frac{\sum(parentcomp_{ij})}{\sum(ijt)}$ where $parentcomp_{ij}$ – a binary variable, for *i* banker of *j* bank	The proportion of bankers who are affiliated with the bank's parent organization, of the total number of bankers
SOB_{jt} and $ForB_{jt}$	$\begin{cases}1 & \text{if } share_{jt} > 50\% \\ 0 & \text{if } share_{jt} \le 50\%\end{cases}$ where $share_{ij}$ – a share of state-owned or foreign entity in *j* bank's equity in *t* year	The binary variables of the state or foreign control over the bank through ownership
$SOSh_{jt}$ and $ForSh_{jt}$	$\begin{cases}1 & \text{if } share_{jt} > 0\% \\ 0 & \text{if } share_{jt} = 0\%\end{cases}$ where $share_{ij}$ – a share of state-owned or foreign entity in *j* bank's equity in *t* year	The binary variables of the state or foreign participation in the bank's equity
$lnNA_{jt}$	$\ln(NA_{jt})$ where NA_{jt} – net assets of *j* bank in *t* year	The bank's size as the natural logarithm of its net assets
$Spets_j$	$\begin{cases}1 & \text{if bank } j \text{ was formed or developed on the basis of former Soviet spetsbanks} \\ 0 & \text{otherwise}\end{cases}$	The binary variable of the foundation or development of the bank based on former Soviet spetsbanks

Principal Components' Analysis for the reduction of the number of political connections variables from 8 to 2 for each of the five types

Two principal components (PCs) were constructed for each of the five types of political connections. The PCs were derived from eight quantitative variables (each with two different values for direct and indirect identification approaches): the natural logarithm of the total number of connected bankers (*common*), the natural logarithm of the number of bankers who have an ongoing connection (*bynow*), the proportion of bankers who obtained a particular type of connection after joining the bank from the total number of bankers with the *common* connection of the same type (*revolv*), the average natural logarithm of the number of years for which a connection lasts (*durat*). Table A.3 presents the loadings (weights) for these variables, showing their contribution in the formation of the two PCs. The proportion of the total variance of the connection variables explained by each of the PCs is given in parentheses.

According to these loadings, the greatest variance of variables for any connection types is contained in the connection duration. The first of the PCs of parliamentary, regulatory and governmental types characterizes mainly informal connections, and the second – the job experience. This also means that the higher variation in these connection types across banks is noticeable precisely in the informal dimension. With regard to the PCs of connections with state-owned companies and regional authorities, this interpretation is difficult, since the first PC of these types fairly evenly absorbs the differences in both work experience and acquaintances. As for the second PC, it is mostly formed by the formal ones for corporate connections, and by informal ones for regional connections.

Table A.3. Loadings of the variables forming the principal components for each of the five types of political connections

Type of political connection	Parliamentary *(parl)*		Regulatory *(regul)*		Governmental *(gov)*		Corporate *(corp)*		Regional *(region)*	
	PC1 (0.74)	PC2 (0.16)	PC1 (0.59)	PC2 (0.32)	PC1 (0.65)	PC2 (0.19)	PC1 (0.61)	PC2 (0.26)	PC1 (0.60)	PC2 (0.24)
Formal common	0.089	0.305	0.122	0.352	0.099	0.464	0.298	0.366	0.273	–0.290
Informal common	0.293	–0.091	0.340	–0.053	0.340	0.148	0.278	–0.142	0.296	0.021
Formal revolving doors	0.070	0.178	0.000	0.000	0.001	0.030	0.049	0.099	0.070	–0.066
Informal revolving doors	0.174	–0.226	0.168	–0.044	0.120	–0.017	0.086	–0.203	0.119	0.010
Formal current status	0.036	0.092	0.035	0.041	0.051	0.201	0.235	0.266	0.127	–0.163
Informal current status	0.206	–0.076	0.213	–0.033	0.260	0.090	0.248	–0.107	0.164	0.116
Formal duration	0.264	0.868	0.229	0.897	0.151	0.795	0.441	0.654	0.597	–0.624
Informal duration	0.870	–0.219	0.862	–0.252	0.876	–0.283	0.716	–0.533	0.648	0.695

Note: The proportion of the total variance of the connection variables explained by each of the PCs is given in parentheses.

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The Effect of Financial Literacy, Social Influence, and Perceived Enjoyment on Cashless Behaviour: The Moderating Role of Facilitating Conditions

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Abstract

Global transactions and technological developments have posed cashless transaction challenges for micro-, small-, and medium-sized batik businesses in Indonesia. Financial literacy, social influence, and perceived enjoyment are the factors that can influence the success of cashless transactions. Furthermore, facilitating conditions can support MSMEs' success in implementing cashless transactions. Therefore, this study aims to analyse the effect of financial literacy, social influence, and perceived enjoyment on cashless transactions in batik MSMEs in Indonesia. In addition, this study also analyses the role of facilitating conditions as a moderating variable. This study uses SEM-PLS and is operated by WarpPLS 8.0. The sample for this research consisted of 100 batik MSMEs from Pekalongan, Central Java, Indonesia. Data collection was conducted over two months. The analysis shows that financial literacy has a significant positive effect on cashless transactions. Moreover, perceived enjoyment also has a considerable positive impact. Furthermore, facilitating conditions can moderate the influence of perceived enjoyment on cashless transactions. However, facilitating conditions fail to moderate both the influence of financial literacy on cashless transactions and the influence of social influence on cashless transactions.

Keywords: batik industry, digital transaction, financial behaviour, non-cash transaction, social factors

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Introduction

Micro, small, and medium enterprises (MSMEs) play an essential role in Indonesia's economic growth. There are 66 million MSMEs in Indonesia, accounting for 61% of gross domestic product (GDP) [1]. Moreover, MSMEs employ 117 million workers, or 97% of Indonesia's total workforce in 2023 [1]. However, MSMEs in Indonesia face challenges in entering the digital transaction era. The number of MSMEs entering the digital ecosystem in 2022 was only 20.76 million [1]. In fact, the Central Bank of Indonesia has facilitated digital transactions for MSMEs, for example, through the Indonesian Quick Response Code Standard (QRIS). Hence, this circumstance illustrates the low level of cashless transaction use among MSMEs in Indonesia. Several factors, such as financial literacy, social influence, and perceived enjoyment, can contribute to the low level of cashless transaction usage in Indonesia.

Financial literacy is the first factor that can affect cashless behaviour in Indonesia. [2] found that MSMEs' financial literacy in Indonesia affects cashless behaviour. A high level of knowledge of MSMEs' understanding of financial management drives their decision to use one of the financial technology products. Moreover, financial literacy can change people's mindsets in making financial decisions, such as applying cashless transactions [3]. Furthermore, financial literacy will increase the number of digital transactions conducted by MSMEs and encourage the transition from a conventional to a modern economy [4].

Besides financial literacy, social influence is another factor that can affect cashless behaviour. According to [5], social influence is the process by which an individual changes their behaviour to adapt to the demands of the social environment; for example, the more people around them use electronic or digital payments, the greater their desire to also use electronic payment tools [6]. Moreover, several parties, such as celebrities, family members, friends, or colleagues, can influence consumer behaviour in adopting cashless payments [5].

Perceived enjoyment can also affect cashless behaviour. Perceived enjoyment is one of the factors influencing behavioural intention to use mobile wallets for cashless transactions in Vietnam [7]. The higher the perceived enjoyment, the greater the intention to use mobile wallets in Vietnam. Furthermore, [8] showed that the effect of the user's perception of enjoyment is more substantial as the user gains more experience with the system over time. [8] found that the more frequently a user uses a system, such as OVO, the stronger the system's influence on the user's intention. [9] found that perceptions of enjoyment influence the intention to use electronic money. The greater the enjoyment of using electronic money, the greater the motivation to use it as a payment instrument.

Facilitating conditions also play an essential role in supporting cashless behaviour. The presence of devices, such as internet-enabled smartphones, knowledge of how to use mobile wallet services, and acceptance of mobile wallet service providers, may encourage the use of cashless transactions [10]. Facilitating conditions are also among the factors that promote the use of e-wallets for cashless transactions [10]. Facilitating conditions have proven to be a significant factor in determining the performance of payment systems [11]. Hence, the government should focus on improving facilities that support cashless transactions [12].

The batik industry is one of Indonesia's growing sectors, dominated by MSMEs. Currently, there are 3,159 batik MSMEs in Indonesia. Furthermore, batik MSMEs also make a significant contribution to Indonesia's economy. According to the Indonesian Ministry of Industry, batik exports in 2020 reached USD 532.7 million, and this figure increased by USD 157.8 million in the first quarter of 2021 alone. Given this economic significance, the digital transformation of batik MSMEs becomes increasingly crucial for sustaining growth. Financial digitalisation in Indonesia encourages MSMEs to use non-cash transactions [13]. The trend of buying and selling products through marketplaces fosters the adoption of non-cash transactions [14]. Hence, financial literacy can assist MSMEs in the batik industry to develop cashless behaviour [15].

Previous studies examined the effect of financial literacy on cashless behaviour [4; 16–18]. Moreover, previous researchers also analysed the impact of social influence on cashless behaviour [5; 6; 19; 20]. Furthermore, the relationship between perceived enjoyment and cashless behaviour has also been discussed in previous studies [8; 9; 21; 22]. Nevertheless, these prior studies obtained different results. Thus, another factor can moderate the effects of financial literacy, social influence, and perceived enjoyment on cashless behaviour. Hence, the novelty of this research lies in applying facilitating conditions as a moderating variable. If digital infrastructure is available and easily accessible, individuals with high financial literacy will be more encouraged to conduct digital transactions. Conversely, if internet access is limited or digital payment systems are unstable, insufficient financial literacy fails to encourage cashless behaviour. The first part of this research discusses the research background. The second part of this research presents the literature review, including theory, prior studies, and hypotheses. Subsequently, the third part will examine the method. The fourth part of this research will present the analysis results and the discussion. The final part forms the conclusion of this research.

Literature Review

Unified Theory of Acceptance and Use of Technology

This research employs the unified theory of acceptance and use of technology (UTAUT), following the approach of [14] and [11]. UTAUT emphasises that performance expectations, effort expectations, social influence, and supporting conditions are the four essential aspects that influence technology acceptance [14]. UTAUT consists of four elements. The first element is performance expectancy, or the belief that applying technology can improve work results and provide clear benefits. The second element is

effort expectancy, or the perception of how easy it is to use technology. The third element is social influence, which is the degree to which a person feels that significant others (friends, family, or co-workers) think they should use technology. Social influence refers to consumers' perceptions that important people in their lives consider this technology necessary [14]. The fourth element is facilitating conditions, which express the perception that infrastructure and resources are available to support the use of technology.

The Effect of Financial Literacy on Cashless Behaviour

According to the UTAUT theory, an increase in financial literacy indicates a stronger tendency to understand the advantages, perceive convenience, and believe in using cashless payment systems. The OECD's financial literacy scale is measured across three main dimensions: knowledge, behaviour, and attitude. Knowledge is an understanding of basic financial concepts, such as interest, inflation, risk, and diversification. Behaviour is how individuals manage money, save, budget, and make financial decisions. Meanwhile, attitude is a perspective on future planning, consumption versus saving tendencies, and long-term orientation. Previous studies discuss the effect of financial literacy on cashless behaviour. [16] discussed the impact of financial literacy on cashless behaviour in the Blora Regency Secretariat. They found that financial literacy has a positive and significant effect on cashless behaviour. Moreover, [17] analysed the relationship between financial literacy and cashless behaviour of MSMEs in Bekasi City, Indonesia. They found that financial literacy has a positive and significant relationship with cashless behaviour. Furthermore, [18] examined the impact of financial literacy on cashless transactions among students in Yogyakarta. They revealed that financial literacy and cashless transactions move in the same direction. [19] discussed the effect of financial literacy on digital financial transactions, such as cashless transactions. As in [18], financial literacy positively affects cashless transactions.

H1: *Financial literacy has a positive effect on cashless behaviour.*

The Effect of Social Influence on Cashless Behaviour

The UTAUT theory emphasises that cashless payment behaviour is not solely driven by efficiency and convenience, but is also shaped by social support, peer pressure, and emerging trends. Strong social influence will increase the intention and implementation of cashless use. Social factors are also among the factors that affect cashless transactions. [20] discussed the impact of social influence on cashless payments. Their study found that social influence positively affects cashless transactions. Social influence can increase an individual's intention to apply and utilise a technology. [5] analysed the influence of social influence on cashless transactions in Malaysia. They found that social influence positively affects cashless transactions. Furthermore, [6] discussed the effect of social influence on the cashless behaviour of Generation Z in Indonesia. They found that social influence has a positive and significant impact on cashless behaviour.

H2: *Social influence has a positive effect on cashless behaviour.*

The Effect of Perceived Enjoyment on Cashless Behaviour

According to UTAUT theory, the enjoyment derived from using digital payment technology serves as an internal driver that strengthens user intentions and behaviour. The higher the level of enjoyment, the greater the chance of widespread and consistent cashless adoption. [21] discussed the effect of perceived enjoyment (affect) on the cashless behaviour of MSMEs in Indonesia. They revealed that emotional response has a positive and significant effect on cashless behaviour. Moreover, [23] discussed the impact of MSMEs' emotional reactions on cashless behaviour in Indonesia. Furthermore, [9] examined the effect of perceived enjoyment on the intention to use electronic money for cashless transactions in Manado, Indonesia. The study found that perceived enjoyment and the intention of using electronic money have a positive influence. In addition, [22] discussed the effect of perceived enjoyment on M-payment (digital payment) as a form of cashless transaction in West Papua. They found a significant effect of perceived enjoyment on M-payment.

H3: *Perceived enjoyment has a positive effect on cashless behaviour.*

Facilitating Conditions as a Moderating Variable of the Effect of Financial Literacy, Social Factors, and Perceived Enjoyment on Cashless Behaviour

Referring to UTAUT, the more optimal the technical support, infrastructure, and resources available, the greater the opportunity for individuals to realise the use of non-cash payments, rather than stop at intentions or motivation. [10] discussed the relationship between facilitating conditions and expectations regarding the use of cashless transactions to implement cashless behaviour in Malaysia. They found a relationship between facilitating conditions and cashless transactions. [11] examined the impact of facilitating conditions on payment system performance as a cashless application. The study found that facilitating conditions are significantly related to payment system performance. [12] analysed the effect of facilitating conditions on the intention to use cashless transactions in Padang Panjang, West Sumatra, Indonesia. They found that facilitating conditions have a positive and significant effect on cashless transactions. Hence, based on those previous studies, facilitating conditions can affect cashless transactions.

Several previous studies also analysed the Quick Response Code Indonesian Standard (QRIS) application as a supporting facility for cashless transactions. [23] discussed

the effects of QRIS on consumer behaviour in Indonesia's cashless society. The study revealed that QRIS is popular because it is practical, fast, and secure, and supports transactions in various denominations. However, this convenience also encourages impulsive consumer behaviour, as users find it easier to spend money without control. [24] analysed the QRIS application for MSMEs in Denpasar City. They discovered that facilitating conditions influence behavioural intentions, suggesting that MSMEs in Denpasar City are encouraged to adopt QRIS due to adequate facilities. While this study focuses on facilitating conditions as a moderator, previous research has also examined other moderating variables, such as gender and awareness of cybercrime. [25] examined the role of gender as a moderating variable in shaping fintech users' continuance intentions in Indonesia. This study shows that gender moderates the relationship between risk perception and continuance intention for fintech use. In addition, [26] investigated the role of cybercrime awareness as a moderating variable in cashless transaction adoption in Indonesia. They showed that awareness of cybercrime can successfully moderate the influence of performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit on the use of cashless transactions. These findings highlight the multifaceted role of enabling conditions in supporting cashless adoption across different contexts.

UTAUT emphasises that facilitating conditions are a determining factor that strengthens the influence of financial literacy on cashless behaviour. With the support of appropriate technology and facilities, digital payment adoption will increase significantly. [27] explored the role of financial access as a moderator variable of the effect of financial literacy on the performance of 155 MSMEs in Kuwait. Their study found that financial access significantly moderates the relationship between financial literacy and MSME performance; greater access to financial services magnifies the benefits of financial literacy.

Social factors can influence individuals to switch to cashless transactions. Still, this influence does not always translate into actual behaviour if supporting facilities, such as QRIS at merchants, are not readily available. According to the UTAUT perspective, adequate supporting conditions are crucial because they amplify social effects, making environmental pressure more effective in encouraging the use of digital payments. [28] investigated the impact of organisational facilitating conditions on technology acceptance and the effectiveness of virtual communities of practice in Spain. They used 110 non-governmental organisations as a sample. [28] found that facilitating conditions positively impact effectiveness and that virtual collaborative interactions also play a significant role.

[29] explored how performance expectations, ease of use, social influence, supporting conditions, and perceptions of enjoyment influence user intentions and behaviour in using online market applications among Tokopedia application users in Denpasar City. They emphasised the importance of optimising the features of online shopping applications to make the interfaces more interactive and user-friendly. Improving the shopping experience and making product discovery easier are believed to encourage greater service usage, while simultaneously strengthening distribution strategies and expanding market reach.

H4: *Facilitating conditions can moderate the effect of financial literacy on cashless behaviour.*

H5: *Facilitating conditions can moderate the effect of social influence on cashless behaviour.*

H6: *Facilitating conditions can moderate the effect of perceived enjoyment on cashless behaviour.*

Method

Data and Research Sample

The sample of this research comprises batik MSMEs in Central Java, Indonesia. Purposive sampling is used as a sampling technique, following [30] and [31] . The sampling criteria are batik MSMEs located in the city of Pekalongan that have used non-cash transaction methods. The sample size was determined using the Slovin formula, as described by [2]. Thus, the total sample of this research was 100 batik MSMEs in Pekalongan, Central Java, Indonesia. This research uses primary data collected from respondents via a questionnaire or Google Form.

Research Variables and Measurement

This research uses three independent variables: financial literacy, social influence, and perceived enjoyment. The dependent variable is cashless behaviour, and the moderating variable is facilitating conditions. In this study, control variables were not used because the primary focus was to examine the direct relationship between the independent and dependent variables. Furthermore, the sample used was relatively homogeneous (all batik MSMEs in the same geographical region with similar business operations), so the influence of external factors was considered minimal. Table 1 presents the variables, definitions, and indicators of all variables in this research.

Analysis Model

This research applies validity and reliability tests. The validity test consists of convergent validity and discriminant validity. The loading factor is used to test convergent validity, and it must be greater than 0.4. Moreover, average variance extracted (AVE) is applied to test discriminant validity. Furthermore, composite reliability is employed to test reliability of latent constructs. All constructs must have composite reliability values greater than 0.6, indicating adequate internal consistency.

This research employs WarpPLS 8.0 to test the research hypotheses. Partial Least Squares (PLS) analysis is a variance-based Structural Equation Modelling (SEM) statistical method designed to address multiple regression problems when specific issues arise in the data, such as missing data, small sample sizes, and multicollinearity [32]. The PLS evaluation model is used to assess the out-

Table 1. Variable Definitions and Indicators

Variables	Definitions	IndiCators
Cashless Behaviour	Cashless behaviour is a habit of people making transactions without using cash, but instead using digital or electronic payment methods.	1. I use non-cash payment methods because they make my job easier. 2. Using non-cash payment methods makes me feel safer. 3. Using non-cash payment methods makes my payment process faster/shortens the time.
Financial Literacy	Individual knowledge and ability to understand how to manage finances, which is measured across three main dimensions: knowledge, behaviour, and attitude.	1. I know the payment methods for non-cash transaction products. 2. I know the implications of non-cash transaction costs. 3. I know the benefits of non-cash transactions.
Social Influence	The influence of significant others and social groups on an individual's decision to adopt particular behaviours in a specific social environment	1. The government issues regulations that encourage the use of non-cash transactions. 2. The use of non-cash transactions is recommended by friends and family. 3. The use of non-cash transactions is recommended by colleagues/supervisors at my workplace. 4. Non-cash transactions are recommended by the community to which I belong.
Perceived Enjoyment	Direct emotional response to a thought about a particular behaviour	1. Using non-cash payment methods creates a sense of practicality. 2. Using non-cash payment methods creates a sense of calm because I can transfer money at any time to colleagues during an emergency. 3. Using non-cash payment methods does not cause concerns.
Facilitating Conditions	Objective factors in an environment that can make a behaviour easier or more difficult, according to each individual's assessment	1. Availability of non-cash payment tools (debit cards, credit cards, e-money, etc.) can be found in the surrounding area. 2. The available communication network is stable when non-cash transactions are carried out. 3. Non-cash transaction tools can be owned with conditions that are easy to fulfil (internal) 4. Non-cash transaction tools are easy to use. 5. The system network for carrying out non-cash transactions does not experience many disruptions.

er model and the inner model. Evaluation of the outer model with reflective indicators is assessed through validity, mainly convergent validity. A reflective indicator is said to have high convergent validity if the correlation is (> 0.60). On the other hand, the evaluation of the inner model (structural model) is done by the percentage of variance explained by the R^2 value. If $R^2 \geq 0.70$, this indicates a strong model; if $R^2 \geq 0.45$, this denotes a moderate model, and if $R^2 \geq 0.25$, this reveals a weak model. Moreover, a partial significance test (t-test) is conducted to determine the extent to which the independent variable influences the dependent variable. The hypothesis is considered accepted if the p-value is < 0.05. Furthermore, the Variance Accounted For (VAF) value is used to evaluate the extent to which the mediation effect influences the whole, based on the indirect effect. Model fit testing is carried out using goodness-of-fit measures. In addition, bootstrap analysis is used to test the significance of the path and estimate the confidence interval of the parameter estimates.

Table 2. Convergent Validity

	Cashless Behaviour	Financial Literacy	Social Influence	Perceived Enjoyment	Facilitating Conditions	M*Z	p-Value
Y1	**0.915**	–0.162	0.014	0.075	–0.035	-0.073	< 0.001
Y2	**0.943**	–0.016	–0.036	0.095	–0.046	–0.017	< 0.001
Y3	**0.890**	0.184	0.024	–0.177	0.085	0.093	< 0.001
X1_1	0.162	**0.814**	0.029	–0.183	–0.010	0.011	< 0.001
X1_3	–0.162	**0.814**	–0.029	0.183	0.010	–0.011	< 0.001
X2_1	0.192	–0.069	0.022	–0.138	–0.144	0.134	< 0.001
X2_2	0.135	–0.077	–0.025	–0.085	0.058	0.019	< 0.001
X2_3	–0.303	0.140	0.011	0.204	0.047	–0.127	< 0.001
X3_2	0.214	–0.126	**0.669**	0.141	0.058	0.092	< 0.001
X3_3	–0.021	0.074	**0.871**	–0.169	–0.017	–0.081	< 0.001
X3_4	–0.135	0.022	**0.921**	0.057	–0.026	0.010	< 0.001
X4_1	0.359	0.137	–0.028	**0.734**	0.003	–0.003	< 0.001
X4_2	–0.266	–0.092	0.081	**0.896**	–0.040	–0.030	< 0.001
X4_3	–0.030	–0.021	–0.061	**0.847**	0.040	0.034	< 0.001
M1	0.311	0.062	–0.109	–0.217	–0.178	0.054	< 0.001
M2	–0.190	0.016	0.099	0.067	0.070	–0.023	< 0.001
M3	–0.045	–0.063	–0.018	0.098	0.065	–0.018	< 0.001
Z2	0.106	–0.135	–0.098	0.017	**0.803**	0.019	< 0.001
Z3	0.065	–0.200	–0.192	0.070	**0.403**	0.432	< 0.001
Z4	0.351	0.371	0.079	–0.172	**0.456**	0.004	< 0.001
Z5	–0.390	0.029	0.172	0.053	**0.697**	–0.276	< 0.001
M*Z	0.000	0.000	0.000	0.000	0.000	**1.000**	< 0.001

Source: Output of WarpPLS 8.0.

Results and Discussion

Results

Validity Test

Table 2 presents the results of the convergent validity test. Table 2 demonstrates that all factor loadings are above 0.4 and the *p*-values are < 0.001; thus, all indicators meet the requirements for convergent validity. Furthermore, the results above indicate that each indicator has a cross-loading value greater than the loading factor value of the other constructs.

Discriminant Validity

Table 3 presents the results of the discriminant validity analysis. According to Table 3, all variables have AVE values above 0.5 (the critical value). Hence, these results indicate that the discriminant validity in this research is valid.

Table 3. Discriminant Validity

	AVE	Critical Value	
Cashless Behaviour	0.916	0.5	Valid
Financial Literacy	0.814	0.5	Valid
Social Influence	0.827	0.5	Valid
Perceived Enjoyment	0.828	0.5	Valid
Facilitating Conditions	0.613	0.5	Valid
M*Z	1.000	0.5	Valid

Source: Output of WarpPLS 8.0.

Table 4. Composite Reliability

Variable	Composite Reliability
Cashless Behaviour	0.940
Financial Literacy	0.797
Social Influence	0.865
Perceived Enjoyment	0.867
Facilitating Conditions	0.690
M*Z	1.000

Source: Output of WarpPLS 8.0.

Composite Reliability

Table 4 presents the results of composite reliability. Table 4 demonstrates that the composite reliability for all variables exceeds 0.6. These results indicate that all constructs have adequate internal consistency.

Goodness-of-Fit Test

Table 5 presents the results of the goodness-of-fit (GoF) evaluation of the structural equation model generated by WarpPLS software version 8.0. Based on Table 5, the Average Path Coefficient (APC) value of 0.192 and *p*-value of 0.007 indicate a statistically significant relationship between the paths in the structural model, as the *p*-value is below 0.05. This means that the average path coefficient indicates that this model is structurally suitable. Moreover, the Adjusted *R*-Squared (ARS) value is 0.593 (*p*-value < 0.01), which is also statistically significant (*p*-value < 0.05), indicating that the model has sufficient ability to explain the variability of the dependent variable based on its independent variables. Furthermore, the Average Adjusted *R*-Squared (AARS) is 0.571 (*p*-value < 0.01); this value is significant (*p*-value < 0.05), indicating that, after adjusting for the number of predictors, the independent variables remain strong enough to explain the dependent variable.

According to Table 5, the Average Block Variance Inflation Factor (AVIF) value of 1.427 is within the acceptable range (less than 5), and ideally below 3.3. This means that multicollinearity among independent variables is not significant in the model. The Average Full Collinearity (AFVIF) value of 1.825 also indicates that there is no serious multicollinearity problem, as this value is below the accepted limit of 5 (ideally ≤ 3.3). Furthermore, the GoF value of 0.681 is categorised as large, with small values below 0.1, medium values between 0.1 and 0.25, and large values above 0.36. This indicates that the model has sufficient predictive power in explaining the dependent variable. A Simpson's Paradox Ratio (SPR) value of 0.833 indicates that there are no cases where Simpson's paradox occurs, meaning that all relationships in the model are in the theoretically expected direction. This value is within the ideal range of ≥ 0.7.

Table 5. Evaluation of Goodness-of-Fit in Structural Equation Models

Parameter	Coefficient	Rule of Thumb	Conclusion
Average Path Coefficient (APC)	0.192, $p = 0.007$	Acceptable $p < 0.05$	Accepted
Adjusted R-Squared (ARS)	0.593, $p < 0.010$	Acceptable $p < 0.05$	Accepted
Average Adjusted R-Squared (AARS)	0.571, $p < 0.010$	Acceptable $p < 0.05$	Accepted
Average Block VIF (AVIF)	1.427	Acceptable if ≤ 5, ideally ≤ 3.3	Accepted
Average Full Collinearity VIF (AFVIF)	1.825	Acceptable if ≤ 5, ideally ≤ 3.3	Accepted
Tenenhaus GoF (GoF)	0.681	small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36	Accepted
Simpson's Paradox Ratio (SPR)	0.833	Acceptable if ≥ 0.7, ideally = 1	Accepted
R-Squared Contribution Ratio (RSCR)	0.982	Acceptable if ≥ 0.9, ideally = 1	Accepted
Statistical Suppression Ratio (SSR)	1.000	Acceptable if ≥ 0.7	Accepted
Nonlinear Bivariate Causality Direction Ratio (NLBCDR)	0.750	Acceptable if ≥ 0.7	Accepted

The *R*-Squared Contribution Ratio (RSCR) value of 0.982 is very close to the ideal value of 1, indicating that almost all the *R*-Squared contribution comes from the expected relationships, indicating a strong and reliable model. Moreover, the value of Statistical Suppression Ratio (SSR) is 1.00, which is higher than 0.7. In addition, the Nonlinear Bivariate Causality Direction Ratio (NLBCDR) value of 0.750, which exceeds 0.7, indicates that the direction of causality in this model's bivariate relationship is consistent with the theory's predictions.

Table 6 describes the estimated relationship across variables. According to Table 6, financial literacy has a positive and significant influence on cashless behaviour. The coefficient value is 0.20, which is significant at the 1% level ($p = 0.01$). Moreover, social influence also positively influences cashless behaviour, with a coefficient of 0.06. Nevertheless, this value is not significant. Similar to financial literacy, perceived enjoyment also has a positive and significant effect on cashless behaviour; the coefficient is 0.59 and is significant at the 1% level ($p = 0.01$). Comparing the coefficient values, perceived enjoyment ($\beta = 0.59$) is the most influential predictor of cashless behaviour, followed by financial literacy ($\beta = 0.20$), while social influence ($\beta = 0.06$) shows a weak, non-significant effect. This suggests that hedonic factors play a more prominent role than cognitive factors in driving cashless transaction adoption among batik MSMEs.

Table 6 also presents the role of facilitating conditions as a moderating variable. According to Table 6, facilitating conditions can only moderate the influence of perceived

Table 6. Estimated Relationship Across Variables

Description Path	Path Coefficient
Financial Literacy on Cashless Behaviour	0.20***
Social Influence on Cashless Behaviour	0.06
Perceived Enjoyment on Cashless Behaviour	0.59***
The Role of Facilitating Conditions as a Moderating Variable of Financial Literacy on Cashless Behaviour	0.09
The Role of Facilitating Conditions as a Moderating Variable of Social Influence on Cashless Behaviour	0.03
The Role of Facilitating Conditions as a Moderating Variable of Perceived Enjoyment on Cashless Behaviour	-0.19**

enjoyment on cashless behaviour; the coefficient is -0.19 and is significant at the 5% level ($p = 0.05$). This result also shows that facilitating conditions weaken the influence of perceived enjoyment on cashless behaviour. Meanwhile, facilitating conditions do not moderate the impact of financial literacy on cashless behaviour. Indeed, facilitating conditions do not moderate the relationship between social influence and cashless behaviour.

Discussion

The Influence of Financial Literacy on Cashless Behaviour

The SEM-PLS analysis shows that financial literacy has a positive and significant effect on cashless behaviour. This positive result is consistent with UTAUT. A high level of financial literacy improves MSMEs' understanding of the benefits and available support, thereby increasing their confidence and sense of security when using digital payment systems. Financial knowledge makes them more confident, better able to minimise risks, and ultimately more open to engaging in cashless behaviour. Moreover, this positive effect aligns with [3; 16–19], . The higher the financial knowledge, the greater the confidence in using cashless or non-cash transactions, for example, via QRIS [3] or digital wallets [19].

The Influence of Social Influence on Cashless Behaviour

The results of the SEM-PLS analysis also indicate that social influence has no significant effect on cashless behaviour. Social influence is not significant in shaping the cashless behaviour of batik MSMEs, as decisions to adopt it are more determined by operational needs, practical benefits, and infrastructure support than by trends or environmental pressures. This result is contrary to those obtained by [5; 6; 20]. The finding that social influence does not significantly affect cashless behaviour may be attributed to several factors. The financial literacy of batik MSMEs remains low, so the use of cashless behaviour is not yet optimal. Furthermore, most batik MSMEs in Indonesia are still accustomed to conventional cash transactions, which is slowing the transition to cashless behaviour.

The Influence of Perceived Enjoyment on Cashless Behaviour

Similar to financial literacy, perceived enjoyment also positively affects cashless behaviour. This result aligns with UTAUT. Perceived enjoyment plays a significant role in driving the adoption of digital payments among batik MSMEs in Indonesia. A pleasant experience with cashless behaviour encourages both consumers and businesses to adopt cashless payment systems, thereby accelerating the digitalisation of the batik sector. Furthermore, this positive impact is consistent with the findings of [9; 21; 22]. Perceived enjoyment, as manifested in emotional responses, can help MSME actors make decisions by guiding their feelings when choosing to use digital transactions [21]. The happier and more excited someone feels about using electronic money, the more motivated they are to use it as a means of payment for goods or services, as it is one of the cashless transaction forms [9].

The Role of Facilitating Conditions as a Moderating Variable of the Effect of Financial Literacy on Cashless Behaviour

The SEM-PLS analysis shows that facilitating conditions do not moderate the effect of financial literacy. Supporting facilities for cashless behaviour cannot strengthen or weaken the influence of financial literacy on cashless behaviour. This condition may occur due to the level of financial literacy. Although supporting facilities for cashless behaviour are available, if financial knowledge about their use is still low, the likelihood is that their availability will not increase or decrease the interest in cashless behaviour.

The Role of Facilitating Conditions as a Moderating Variable of the Effect of Social Influence on Cashless Behaviour

Support for cashless behaviour cannot strengthen or weaken the influence of social factors on cashless behaviour. This situation is likely due to batik MSMEs' cash-based practices. Generally, batik businesses in Indonesia are hereditary. This situation sometimes affects company management, especially its financial management, which remains conventional and reluctant to adapt to the evolution of current digital transactions. Therefore, the existence of supporting facilities for cashless behaviour does not have a role in the relationship between social influence and cashless behaviour.

The Role of Facilitating Conditions as a Moderating Variable of the Effect of Perceived Enjoyment on Cashless Behaviour

The analysis found that facilitating conditions weaken the effect of perceived enjoyment on cashless behaviour. In UTAUT, strong facilitating conditions make cashless adoption among batik MSMEs more dependent on functional aspects and system support, thereby reducing the influence of perceived enjoyment on user behaviour. This negative moderating effect suggests that when technological infrastructure is robust and reliable, users shift their focus from hedonic motivations to utilitarian benefits, aligning with the instrumental perspective of technology acceptance. In other words, when the facilitating conditions are in place, enjoyment is no longer the primary factor in determining digital payment usage.

Conclusion

The digital transformation of Indonesia's economy presents both opportunities and challenges for batik MSMEs, particularly in adopting cashless transaction systems. Technological developments have facilitated the emergence of cashless transactions, creating new imperatives for traditional businesses to adapt. Therefore, this study examines the influence of financial literacy, social influence, and perceived enjoyment on cashless transac-

tions among batik MSMEs in Indonesia. Moreover, the SEM-PLS analysis shows that financial literacy and perceived enjoyment have a significant positive influence, whereas social influence does not. Facilitating conditions as a moderating variable weaken the influence of perceived enjoyment on cashless transactions. Meanwhile, this moderating variable cannot moderate the effects of financial literacy and social influence on cashless transactions.

Specifically, two of the three main hypotheses were supported: H1 (financial literacy positively affects cashless behaviour) and H3 (perceived enjoyment positively affects cashless behaviour). In contrast, H2 (social influence positively affects cashless behaviour) was rejected. Regarding the moderation effects, only H6 (facilitating conditions moderate the impact of perceived enjoyment on cashless behaviour) was supported, whereas H4 and H5 were not supported.

This study contributes theoretically by introducing facilitating conditions as a moderating variable, thereby presenting a novel perspective in the literature. Facilitating conditions, such as infrastructure, regulations, and accessibility, have been shown to strengthen or weaken the influence of perceived enjoyment, financial literacy, and social influence on cashless behaviour. Thus, the literature is expanded by understanding that facilitating conditions act not only as direct predictors but also as interacting factors. This finding enriches the UTAUT framework by demonstrating that contextual factors play a more complex role than previously understood, particularly in traditional MSMEs in developing economies.

This research provides a practical contribution, incentivizing MSMEs, consumers, regulators, and financial service providers to accelerate the adoption of digital payments. By emphasising the importance of financial literacy, social influence, and enjoyment, and considering the moderating role of facilitating conditions, all stakeholders can design more effective strategies to support the creation of a cashless society. Specifically, policymakers should prioritise infrastructure development, educators should enhance financial literacy programmes tailored to MSMEs, and technology providers should focus on creating enjoyable user experiences while ensuring robust system reliability.

For batik MSME owners and managers, these findings suggest that enhancing financial literacy through training programmes and creating enjoyable user experiences should be prioritised. Additionally, collaboration with technology providers to ensure reliable infrastructure and user-friendly payment systems can facilitate smoother transitions to cashless operations. Government agencies and industry associations should work together to provide comprehensive support systems that address both the knowledge gaps and the infrastructural requirements necessary for successful cashless adoption.

This study focuses exclusively on batik MSMEs; therefore, further research can examine cashless transactions in other company sectors to enhance the generalisability of the findings. In addition, this study uses only financial literacy, social influence, and perceived enjoyment as variables influencing cashless transactions. In fact, other factors, such as perceived ease of use and perceived usefulness, can also influence cashless transactions. Furthermore, additional factors, such as financial technology capabilities and regulations governing non-cash transactions, can serve as moderator variables.

Furthermore, this study is limited by its geographical focus on Pekalongan, Central Java, and its cross-sectional design, which limits causal inferences. The reliance on self-reported data may also introduce response bias. Future research should employ longitudinal designs to capture temporal dynamics in cashless adoption patterns and to observe how facilitating conditions evolve. Additionally, future studies could employ mixed methods approaches to gain deeper insights into the barriers and enablers of cashless adoption. Comparative studies across different regions or countries could enhance the generalisability of the findings and reveal cultural or contextual factors that influence the relationships examined in this study. Expanding the sample to include larger enterprises or different industry sectors would also provide valuable insights into how firm size and industry characteristics affect the adoption of cashless behaviour.

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