



Finding the governing differential equations in free form through data analysis

Prof - Fardeen Ali Khan

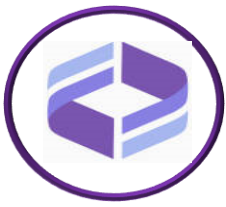
University of Lahore at-Fardeen464@gmail.com

Abstract:

This paper proposes a methodology for the identification of governing differential equations based on empirical data. This method does not require any a priori specification of the equation's constituent pieces to be carried out in order to be successful. Because of this, there is no requirement for a pre-determined specification of the components that are to be included. The strategy that has been suggested has as its primary objective the simplification of the incorporation of a dataset or a set of datasets that are relevant to a particular solution or a group of particular solutions of a differential equation. The problem-solving approach that has been suggested is developed with the purpose of being flexible enough to adapt to either scenario. The end result is a differential equation that has been written down in a way that is simple enough for folks to comprehend. The equation has been changed and tweaked in order to provide a more accurate representation of the particular solutions that have been presented. Improving one's understanding of differentiable data models is the primary objective of this research project. In the following step, the outputs that are produced by these models are then utilized as inputs inside the framework of genetic programming. This approach makes use of graphical representations to explain calculations by employing a wide variety of functions, parameters, and sometimes differential operators that are applied to functions. Our method, which makes use of recursive applications of automatic differentiation, has the capacity to investigate any arbitrary combination of operators without needing any input from the user. This is made possible by the fact that it employs automatic differentiation. This method makes it easier to simplify the design and evaluation of differential operators. It also makes the process more efficient. In addition, we describe a methodology for participating in active learning with the purpose of identifying and addressing flaws within the suggested governing equations. Our ultimate goal is to improve the system. The implementation of this measure was done so in order to improve the accuracy of the results.

Introduction

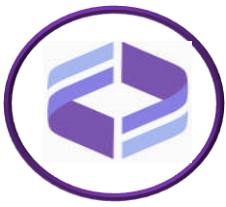
The objective of this research is to conduct a thorough examination of academic articles on the corporate governance of banks, namely those published from 1990 to 2018. The assessment process comprises two distinct stages: Our first step will include doing an extensive literature study to identify academic papers relevant to this particular area of concern. Subsequently, we



use a meta-analysis methodology to thoroughly assess the results of prior research. Due to the significance of these three elements of bank corporate governance for scholars and policymakers, our research focuses on three primary domains: risk management, ownership structure, and CEO remuneration. We examined three primary topics. In essence, banks generate profits by partaking in venturesome lending activities. Following the crisis, the significance of the risk management function has significantly increased due to its crucial role in mitigating risks, which have been shown to be insufficient and below the expected level (Brogi and Lagasio, 2018). The significance of risk aversion plays a role in the development of this focus. The source cited is McConnell (2011). Recently, banking regulatory bodies have finally released long-awaited requirements on sound corporate governance. National authorities have implemented numerous steps to enhance the regulatory and supervisory monitoring of risk governance in financial institutions, leading to improvements in this area. The purpose of this action is to enhance the board of directors' jurisdiction and responsibilities, while simultaneously ensuring effective risk management in light of evolving circumstances (Brogi, 2011).

These measures encompass the implementation of new regulations or the strengthening of current guidance, the elevation of supervisory expectations for the risk management function, the enhanced participation of the board and management, and the assessment of the precision and utility of the information provided to the board to ensure its effective discharge of responsibilities. (FSB, 2013). The recognition of the board's accountability in risk management, as outlined in Basel II's second pillar, highlighted the need of aligning the internal governance framework with the overarching risk management plan. Academic experts and government officials assert that creating an autonomous Chief Risk Officer (CRO) and/or Risk Management Committee is a crucial internal governance mechanism that enhances the overall risk management framework. These individuals are responsible for overseeing all risks taken on by the bank. Large corporations, especially those in the financial sector, are progressively assigning the responsibility of risk management to a committee inside the board of directors (OECD, 2017). In 2013, the European Parliament urged member states to implement laws and procedures that ensure efficient management supervision and promote a robust risk culture across all levels of credit institutions and investment businesses. Furthermore, it will enable the relevant authorities to oversee the effectiveness of internal governance procedures. To assess the advancements made by national authorities in the implementation of their operations. In February 2013, the Financial Stability Board (FSB) released a thematic assessment on risk governance as a continuation of its dedication to peer review. The objective of this research is to thoroughly assess the current state of risk governance in the banking sector after the global financial crisis. The peer review conclusions have led to the concurrent implementation of risk governance enhancements by national authorities and financial institutions.

However, standard setters have mostly focused their attention and expertise on the immediate effects of the most recent financial crisis. However, it is imperative for national governments and banks to intensify their efforts in creating robust risk governance frameworks and establishing explicit requirements for third-party assessment. Financial firms must provide Chief Risk Officers (CROs) more responsibility and influence in their positions. It is essential for



national regulators to enhance their ability to assess the effectiveness of a bank's risk governance and culture, as an example. This is an illustration of something crucial. Additionally, it is recommended that they increase their frequency of communication with the board of directors and its risk and audit committees (BCBS, 2015). Due to the inquiry's results, which demonstrate a progressive growth in the relevance of this issue since the crisis, the scholarly literature continues to generate conflicting perspectives. Shleifer and Vishny (1986) have mostly concentrated their study on corporate governance in the banking industry with a specific emphasis on business ownership structures. Berle and Means (1932) were trailblazers in the field when they examined it from a commercial perspective. Their study illuminates the issue of separation between ownership and control, which poses a concern for the survival of organisations in situations where decision-makers have little concern for the financial outcomes of their actions (Fama & Jensen, 1983b). Prior researchers have investigated it in subsequent time periods.

Additionally, they noted that the fragmented ownership structure inside the organization had an adverse effect on the company's performance. Jensen and Meckling's agency theory, published in 1976, portrays managers as agents whose primary objective is to optimise the well-being of shareholders, referred to as principals. Jensen and Meckling (1976) argue that agents who are not owners may encounter "moral hazards" when they are involved in situations where ownership and control are shared. This is because their interests are not aligned with the interests of the principals. Jensen (1983b) concurs with this viewpoint and asserts that there are two unique methodologies that may be used to tackle issues that affect large corporations. The first phase involves synchronising the risk propensity of principals and agents, whereas the subsequent phase entails enhancing the mechanisms for overseeing ownership composition. Two eminent scholars in the area of agency theory have extensively researched the notion of concentrated ownership as a governance mechanism that has the potential to decrease agency costs. The scholars in question include Glassman and Rhoades (1980) as well as Shleifer and Vishny (1997). Both of these specialists have made substantial contributions to the field. An important challenge that arises in companies with highly consolidated ownership structures is the presence of "horizontal" agency issues. Conflicts arise when majority shareholders and minority shareholders collide. Conversely, conflicts related to the relationship between management and shareholders, known as "vertical" difficulties, might potentially be handled (Vermeulen 2013). Over the last decade, nations with ownership systems that are spread out have taken measures to tackle "horizontal" agency problems that might arise between majority and minority shareholders (OECD, 2017).

Literature Review

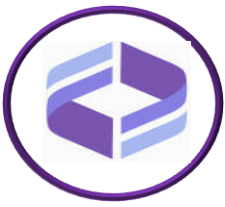
The empirical study demonstrated that the academic literature encompasses a variety of viewpoints about the correlation between bank corporate governance and risk management. yield facts that are pertinent to this specific area of inquiry. Aebi et al. (2012) analyse data from 573 banks in the United States between July 1, 2007 and December 31, 2008, to determine if risk management-related Corporate Governance procedures had a positive impact on bank performance during the 2007/2008 financial crisis. This research aims to examine the influence of



a chief risk officer (CRO) on a bank's executive board, as well as the CRO's reporting hierarchy (whether reporting to the CEO or directly to the board of directors), on the bank's performance. Performance is assessed via the use of buy-and-hold returns and return on equity (ROE), in addition to many corporate governance aspects like CEO ownership, board size, and board independence. The study's findings indicate that financial institutions that have a Chief Risk Officer (CRO) who reports directly to the Board of Directors, rather than the CEO, get better results in terms of performance criteria. Ellul and Yerramilli (2013) provide a similar finding to the one we have got in our study. A study was conducted to examine the influence of a robust and independent risk management system on the risk-taking behaviour and performance of seventy-four prominent banks in the United States. The study covers the years 1995 to 2010, and the researchers assess the data from that specific timeframe. The production of a Risk Management Index (RMI) has five components, each of which evaluates the efficacy of a bank's risk management (CRO).

The variable "present" is a binary indicator that determines whether or not the Bank Holding Company (BHC) has a Chief Risk Officer (CRO) in its employment. The variable "Present" is kept in the database. The "CRO Executive" variable is a binary indication that signifies the presence or absence of an executive role for the Chief Recruitment Officer (CRO). The variable "CRO-Top5" is a binary indicator that denotes whether the Chief Revenue Officer (CRO) is ranked inside the top five highest paid executives or not. The term "CRO" denotes the position of Chief Risk Officer. Centrality is a numerical assessment of the proportion between the overall compensation of the Chief Executive Officer (CEO) and the total remuneration of the Chief Risk Officer (CRO), which indicates the level of incentive given to the CRO. Based on the authors' research, banks that had a higher RMI value in 2006 fared better than other institutions throughout the crisis and showed a lower degree of risk. Banks that exhibited superior risk management in 2006 had a decrease in tail risk and a lower number of non-performing loans, hence substantiating their assertions. Zagorchev and Gao (2015) analysed the results of a study investigating the influence of Corporate Governance on financial institutions in the United States from 2002 to 2009. The researchers used 41 criteria to construct the Corporate Governance index (CG41) offered by RiskMetrics. The authors' research reveals a correlation between enhanced governance and reduced risk-taking, which may be assessed via non-performing assets and real estate non-performing assets. Moreover, the study results clearly demonstrate a strong correlation between enhanced governance and performance, as assessed by Tobin's Q. In their study, Mongiardino and Plath (2010) examined the role of independent directors in the management of risk. Based on the study results, it is necessary to establish a professional risk committee at the board level in order to effectively manage risks.

The findings suggest that a significant proportion of the committee's members should possess impartiality. Additionally, it is suggested that the financial institution's executive board hire a chief risk officer (CRO). In a survey conducted in 2007, it was found that just a small fraction of the most renowned banks met the specified criteria. Most risk committees lacked a sufficient number of members who had both financial expertise and independence. Kanagaretnam et al. (2010) examine the correlation between auditor fees and the extent of profit manipulation



via loan loss provisions in the banking industry. The purpose of this research is to assess the degree of auditor independence. The researchers deduce that the degree to which auditors depend on audit client fees is linked to the manipulation of profitability via the use of atypical loan loss provisions, especially in the setting of small banks. Consequently, the authors strongly advocate for governments to enact new legislation in response to the current financial crisis. Barakat and Hussainey (2013) provide an additional method to complement the current one. In order to enhance risk disclosure, it is recommended that unbiased and competent national committees or task groups be established. These committees or bodies would have the capacity to oversee and provide counsel on the issue.

Methodology

Sample Size

We do a comprehensive assessment of the existing research, which involves the following stages:

1. Choose a suitable source for your fully completed business.

ScienceDirect² is recommended as a research database.

2. Limit the selection to publications published in journals that undergo a peer-reviewed assessment procedure.

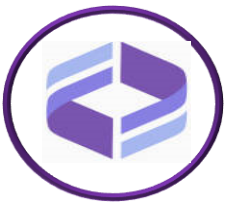
3. Conduct a search for the terms "Corporate Governance" and either "banks" or "financial institutions" simultaneously.

4. Due to the growing emphasis on risk management, ownership structure, and pay by supervisors, the sample should only include publications that specifically address these topics.

5. Verify the relevance of the articles by thoroughly reading the abstracts and then reading the whole articles to confirm the significance of their contents.

6. Consolidate your discoveries.

The predominant emphasis of the research on the chosen issue has been on the possible hazards encountered by banks and the essential skills they need to acquire. Research typically examines the relationship between risk management, ownership structure, remuneration, and their influence on performance drivers and dangers. The responsibilities of the risk management function include the identification, quantification, surveillance, and counsel on risk mitigation and abatement techniques. Furthermore, it provides data on the risk exposures of businesses to

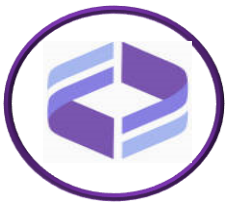


guarantee a risk profile that aligns with the board of directors' authorised Risk Appetite Framework (RAF). The correlation between executive income and risk arises from the potential for excessive risk-taking due to an insufficient incentive system. This correlation arises due to the fact that CEO compensation is directly tied to the level of risk involved. Extensive research suggests a connection between ownership structure and concentration in relation to risk and performance.

Meta-analysis

The use of meta-analysis may provide a thorough and all-encompassing assessment of the development of the body of research on bank corporate governance. According to the discoveries made by Hunter and his colleagues in 1982. As per the description provided by Soussi and Khlif (2012), the latter approach refers to a methodical technique that seeks to align and integrate the findings of prior research on a particular topic. This approach comprises two stages: firstly, implementing the model to acquire a comprehensive comprehension of the prevailing correlation between corporate governance and the independent variables (such as risk and performance); and secondly, conducting the analysis on distinct corporate governance characteristics identified by homogeneous subgroups of variables (related to risk management, ownership, and concentration) to precisely establish the The statistics proposed by Higgins and Thompson (2002) and Higgins et al. (2003) are used to conduct a comprehensive analysis of heterogeneity and ascertain the sample's conformity with great accuracy.

The equation $I^2 = x^2 - df$ represents the statistical correlation between x^2 and the probability degrees of freedom, df . Using these data, we can compute the proportion of variability that might be attributed to heterogeneity rather than sampling error. After thoroughly examining the whole sample, we have determined that the coefficient of determination (C^2) is 0.92. Consequently, 92% of the variation may be ascribed to heterogeneity, suggesting that the studies in the sample are not part of the same population. To tackle the problem of heterogeneity, there are two approaches that can be employed. Firstly, a random effects model with a Gaussian distribution can be utilised to evaluate the efficacy of different studies (Fleiss & Gross, 1991; DerSimonian & Laird 1985; Ades & Higgins, 2005; Higgins et al., 2009). Secondly, a subgroup analysis can be conducted to examine the interactions that take place within each distinct subgroup. Both of these strategies were addressed in the preceding section. The random effects



model is first conducted with a 95% confidence level, assuming that the real impact may differ throughout the whole sample (Borenstein et al., 2009). The model given here was constructed using Pearson's correlations between the independent and dependent variables. The connections were established by a bivariate correlation analysis. When dealing with variables that are strongly linked, it is crucial to make further adjustments to the skewness of the sample distribution. Pearson's correlation coefficient is limited inside the range of -1 to 1, meaning it can only assume values within that interval. The Pearson correlation coefficient is a statistical measure that ranges from -1 to 1. The Fisher's r-to-z transformation is used to convert the non-normal distribution (r) into a Gaussian distribution (z) with a variance coefficient that is not influenced by the initial estimated correlation. This is achieved by transforming the skewed distribution into a Gaussian distribution.

This change will be applied to the calculated Pearson correlation coefficient. The estimation of standard error is influenced by the sample size of each specific research. The below equation represents the method for computing the standard error value: The mathematical function is represented by the formula $z - 1/2 \log(1 + r)/(1 - r)$. The formula states that μz is equivalent to μ and σz is equal to 1 divided by the square root of n minus 3, where n is the size of the sample. In the i-study, the within-study variance is equal to the sum of one and the between-study variance, shown by the symbol W_y . The technique used to ascertain the weight of each research, represented by the symbol W , is as follows. When accounting for random influences, the weight is computed using the method described below. The value of X is equal to 2 times the sum of X and X multiplied by 2. Ultimately, we may calculate the variance and predicted standard error of the overall effect using the prescribed procedures outlined below. The equations $VM = 1$ and $SQM = \sqrt{VM}$ are applicable for this purpose. The equations use the weighted mean M technique. The equation may be written as the summation of the product of $W_i Y_i$ and k_i , where i ranges from 1 to M . Here, M represents the total number of components in the equation. This expression may be used to denote an equation.

The lower and upper limits will be calculated using the following equations: $XLM = M - 1.96 * SEM$ and $UXM = M + 1.96 * SEM$. The findings are derived from a statistical study conducted with a confidence level of 95%. The meta-analysis relies on findings derived from prior scholarly investigations of bank ownership structures and corporate governance. This is because



the approach necessitates the inclusion of a certain number of articles in the sample. Furthermore, the plan necessitates that the publications adhere to a standardised process. Consequently, the meta-analysis omits all of the research subjects addressed in this paper. On the contrary, it explores the correlation between the structure of ownership and the performance and risk of banks in more depth. A thorough literature evaluation, similar to the one previously mentioned, was undertaken to examine many research topics, including risk management and compensation remuneration.

Results

Initially, we do a meta-analysis of a compilation of studies that examine the correlation between bank ownership structure and performance. Table 1 presents a concise overview of the research outcomes. Research on ownership structure in the banking sector continuously demonstrates that it has a crucial role in enhancing bank performance. Table 2 presents the results of the subgroup analysis, which aim to facilitate the comprehension of the interconnections among the examined components. Several studies have focused on the correlation between bank performance and the four primary types of ownership. These characteristics include the board of directors' ownership (the percentage of capital held by the bank's directors), CEO ownership, controlling shareholders' ownership (the percentage of capital controlled by the controlling shareholder), and state ownership. The subgroup analysis reveals a positive correlation between the bank's performance and the ownership of the Board of Directors, Chief Executive Officer, and controlling shareholders. The coefficients were 0.03 and 0.28. Given the very narrow confidence intervals, both of which are in the positive range of the x-axis (with the lower limit at 0.25 and the upper limit at 0.33), it is reasonable to infer that the CEO ownership link is the most prominent. Conversely, there seems to be a significant inverse link between state ownership and bank performance, with a correlation coefficient of -0.18 and a confidence range of -0.24--0.26. - 0.12).

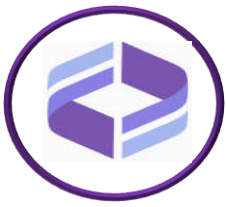


Table 1

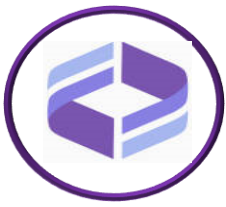
Study number	Correlation (z)	Number of subjects	Variance (z)	Standard error (z)	Weight (random)	CI Lower limit	CI Upper Limit	Weight %	Residuals	ES Forestplot	CI Bar LL	CI Bar UL
1	-0,12	111	0,00936	0,2	23,08	-0,32	0,05	0,03	-0,3	-0,12	0,18	0,18
2	-0,21	348	0,00288	0,04	27,05	-0,30	-0,12	0,03	-0,4	-0,22	0,1	0,1
3	0,31	219	0,00464	0,06	25,85	0,20	0,45	0,03	0,19	0,32	0,12	0,12
4	0,31	215	0,00475	0,06	25,77	0,2	0,44	0,03	0,19	0,32	0,13	0,13
5	0,21	210	0,00480	0,06	25,77	0,1	0,34	0,03	0,07	0,22	0,13	0,13
6	0,21	214	0,00470	0,06	25,75	0,1	0,34	0,03	0,07	0,22	0,13	0,13
7	0,21	209	0,00489	0,06	25,66	0,1	0,35	0,03	0,07	0,22	0,13	0,12
8	-0,02	635	0,00159	0,05	28,00	-0,13	0,03	0,03	-0,20	-0,03	0,08	0,08
9	-0,20	215	0,00477	0,06	25,77	-0,30	-0,04	0,03	-0,35	-0,18	0,13	0,12
10	-0,07	1 535	0,00064	0,02	28,80	-0,10	-0,01	0,03	-0,25	-0,05	0,05	0,05
11	0,18	289	0,00350	0,05	26,61	0,05	0,29	0,03	0	0,16	0,11	0,11
12	0,07	1 355	0,00073	0,02	28,75	0	0,1	0,03	-0,13	0,05	0,05	0,05

Table 2

Subgroup name	Correlation	CI Lower limit	CI Upper limit	Weight	I2	T2
Board Ownership	0,03	-0,14	0,24	0,25	0,90	0,02
CEO Ownership	0,28	0,25	0,33	0,25	0,88	0,03
Controlling Shareholders	0,12	-0,05	0,28	0,25	0,66	0
State Ownership	-0,19	-0,25	-0,11	0,25	-	-
Combined effect size	0,06	-0,12	0,25		0,91	0,03

Ownership and risk

The second research analyses a range of publications to determine the relationship between ownership and risk. The present study's results suggest that the significance of the outcomes has diminished compared to earlier research, particularly in relation to ownership and performance. Prior academic investigations on this matter resulted in a single conclusion. The subgroup



analysis results suggest that a significant proportion of the academic community is unable to choose among the provided options. The analytical data are shown in Table 4. Possible subgroups in this scenario consist of the dominant shareholder, the CEO's equity, and government ownership. All three samples have a negative correlation coefficient. Nevertheless, the confidence intervals exhibit a considerable degree of uncertainty, rendering it unfeasible to draw any conclusive inferences about the investigation's value or the facts it uncovered.

Table 3

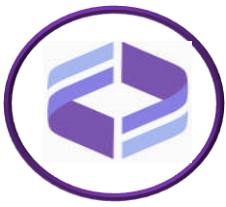
<i>Study number</i>	<i>Correlation (z)</i>	<i>Number of subjects</i>	<i>Variance (z)</i>	<i>Standard error (z)</i>	<i>Weight (random)</i>	<i>CI Lower limit</i>	<i>CI Upper Limit</i>	<i>Weight %</i>	<i>Residuals</i>	<i>ES Forestplot</i>	<i>CI Bar LL</i>	<i>CI Bar UL</i>
1	-0,2	350	0,00290	0,04	63,74	-0,2	-0,1	0,05	-0,21	-0,2	0,1	0,1
2	0,19	97	0,01076	0,1	42,47	-0,01	0,38	0,03	0,16	0,18	0,2	0,18
3	0,03	299	0,00340	0,05	61,77	-0,08	0,12	0,05	0	0,02	0,11	0,10
4	0,10	1 535	0,00066	0,04	74,34	0,03	0,15	0,06	0,07	0,09	0,05	0,04
5	-0,14	289	0,00352	0,05	61,32	-0,25	-0,01	0,05	-0,15	-0,12	0,11	0,11

Table 4

<i>Subgroup name</i>	<i>Correlation</i>	<i>CI Lower limit</i>	<i>CI Upper limit</i>	<i>Weight</i>	<i>I2</i>	<i>T2</i>
CEO Ownership	0,05	-0,15	0,22	0,30	0,97	0,01
Controlling Shareholders	0,05	-0,02	0,1	0,40	0,51	0,01
State Ownership	-0,14	-0,68	0,4	0,30	0,51	0
Combined effect size	-0,03	-0,14	0,13		0,83	0,01

Conclusion

Individuals are acquiring a greater understanding of the fundamental concepts of bank corporate governance, including risk management and ownership structure. This comprehension is spreading across the general populace. It serves as compensation for misdeeds. This is the final result that was generated by considering the viewpoints of both the banking industry and the institutional sector. The technique involves doing a comprehensive literature study of various publications that are pertinent to the topic, as well as performing a meta-analysis to evaluate the



findings of previous scholarly research on the correlation between ownership and bank risk and performance. Following the crisis, there has been a substantial surge in academics' interest to risk management, as indicated by a detailed literature review. Moreover, it illustrates that published literature often yields inconclusive findings. Agency theory posits that executive remuneration, particularly its variable component, is widely recognised as a means to align the interests of managers and shareholders and enhance the performance of executives (Berle & tool, 1932; Holmstrom, 1979; Grossman & Hart, 1983; Murphy, 1985). This is due to the fact that executive compensation often has a variable element. This theory is the foundation for the current academic discourse on compensation in the banking sector. Nevertheless, there is a dearth of agreement about the correlation between performance and compensation, which is especially pertinent in this specific situation. This poses a problem, as mentioned above. According to the managerial power theory (Bebchuk et al., 2010), executive incentive compensation creates a misalignment between the objectives of executives and shareholders. This concept proposes that executive incentive pay functions as a mechanism.

Conversely, there is a widespread agreement that a higher compensation might lead to a rise in risk-taking behaviour among bank managers. A significant majority of folks endorse this concept. The meta-analysis done on ownership yields fascinating findings in comparison to previous academic investigations. For instance, although it is feasible to draw several conclusions about the relationship between ownership and risk, examining the correlation between ownership and bank performance reveals a distinct and noteworthy discovery. The subgroup analysis revealed that controlling shareholders, CEO ownership, and Board ownership had a favourable influence on bank performance. When the opposite is the case, there exists an inverse correlation between state ownership and banking performance. Nevertheless, this approach has its limitations. Higgins and Thompson (2002) argue that prejudice stems from sample selection bias. This bias arises from the presence of variety and the challenge of comparing disparate entities. Due to the results of the meta-analysis, no definitive conclusions could be drawn on the examined problem. It is recommended, from a methodological perspective, to conduct further sensitivity tests to see whether using other selection criteria or making various assumptions in the strategy leads to different results. Scholars with an interest in this issue are likely to do more



research on the variations in corporate governance, performance, and risk within the banking sector across different nations.

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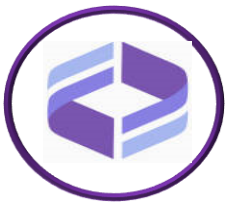
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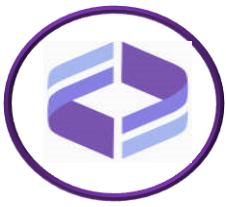
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