# Beyond CAPM: Operational Efficiency, Market Dynamics, and Sustainable Banking as Drivers of Systematic Risk in Emerging Market Banks

*Tayyaba Rani*

*Xi'an Jiaotong University, China*

**Abstract**

Maintaining financial stability in emerging market banking sectors is essential for sustainable economic development. In such economies, banks play a central role in financial intermediation, making their stability crucial for macroeconomic resilience. This study investigates the determinants of systematic risk in the Pakistani banking sector by extending the traditional Capital Asset Pricing Model (CAPM) to incorporate operational characteristics and sustainability-related factors. Using panel data for listed commercial banks on the Pakistan Stock Exchange over the period 2007–2024, the study estimates time-varying beta coefficients through rolling regressions. These beta estimates are then analyzed using fixed-effects panel regression models to assess the impact of bank size, operating efficiency, market share, competition, and ESG performance. The empirical findings suggest that larger banks exhibit significantly higher systematic risk, while operational efficiency and ESG performance contribute to reducing market sensitivity. Moreover, ESG factors are found to moderate the relationship between structural characteristics and risk exposure, indicating their role in enhancing financial resilience. The study contributes to the literature by integrating financial theory with sustainability considerations, offering a more comprehensive framework for understanding banking sector risk in emerging markets. The findings provide important policy implications for regulators seeking to balance financial stability with sustainable development objectives.

**Keywords:** Systematic risk; CAPM; Banking sector; ESG; Financial stability; Emerging markets; Pakistan


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## 1. Introduction

Financial stability is a key determinant of sustainable economic development in emerging markets, where disruptions in the banking sector can have profound effects on growth, investment, and socioeconomic conditions (Curcio, Gianfrancesco, Onorato & Vioto, 2024). Systemic risk—the potential for distress in a single financial institution to propagate throughout an entire financial system has gained renewed attention in both academic and policy debates, particularly after the global financial crisis and subsequent market stress events. Traditional frameworks, such as the Capital Asset Pricing Model (CAPM), have long been used to assess systematic risk but often fall short of capturing broader structural and sustainability- related drivers that shape risk dynamics in evolving markets. Empirical studies have recently demonstrated the increasing significance of the Environmental, Social, and Governance (ESG) performance in determining the financial stability outcomes. An increase in the ESG scores of non-financial firms can mitigate systemic risk among European banks and insurers, which proves that the sustainability related performance has an impact on the transmission channels of risks in the financial system (Rani et al., 2018). The result aligns with the larger body of evidence that the exposure of financial institutions to factors of sustainability influences stability, and the integration of ESG into risk assessment models is necessary. Sustainability concerns are becoming more relevant when it comes to the resilience of the banking sector in the context of emerging markets. Sustainable finance practices, as indicated by the ESG dimensions, play a role in financial stability of Pakistan Stock Exchange listed banks, which shows the increasing importance of sustainable finance in resilience building (Nazir et al., 2024). In addition, the systemic risk spillovers research in South Asia demonstrates that the dynamic relationship between stock markets and banking deposits, which can be frequently associated with the sustainability orientations, can significantly influence financial vulnerability in case of market stress (Liu, et al., 2024). All these studies highlight that sustainability and risk are not two distinct areas: they are interdependent and influence financial performance and systemic vulnerability. Figure 1 that indicates the relationship between Bank Size (log Assets) and systematic risk (Beta, 2). The points are the banks, and the colour is the ESG score of the bank, showing how sustainability can work to moderate the risk. The dashed line shows the overall trend of Beta increasing with bank size.

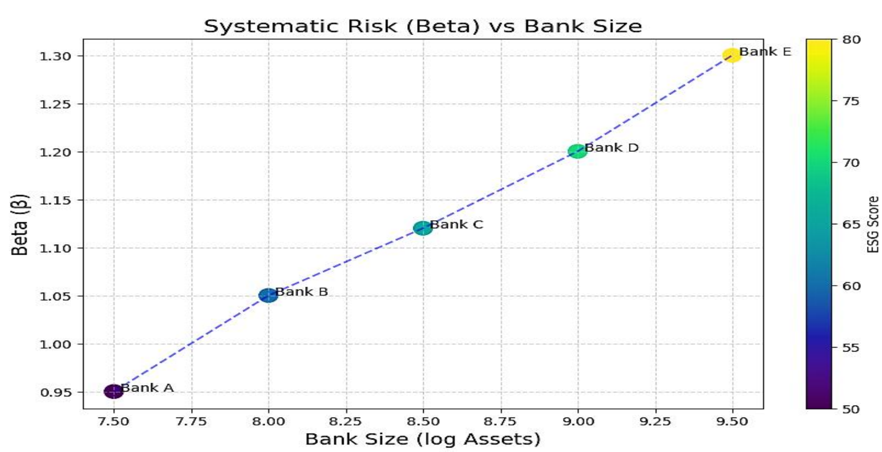


**Figure 1**: Beta (β) values across banks by size, highlighting ESG moderation.

This notwithstanding, the literature on the interaction between bank specific operational attributes (size, efficiency, and competitive intensity) and sustainability determinants of systemic risk in a single analytical framework is still lacking, particularly in respect to emerging markets such as Pakistan. This gap is critical, and big, interconnected banks can be amplifiers of systemic risk, unless their operational profiles and sustainability orientations are fully comprehended and reflected in regulatory frameworks. This paper fills this gap by extending CAPM framework to include operational determinants and sustainability related considerations in the measurement of systemic risks. Based on daily stock returns data of the Pakistan Stock Exchange in the 2007 to 2024 period, we empirically determine the joint effect of bank size, operating efficiency, and market competition on the systemic risk in an emerging market setting. This study adds to both theory and practice by introducing sustainability concerns to the conventional systemic risk estimation to provide evidence to regulators and financial policymakers in Pakistan and other emerging economies in an effort to achieve financial stability and sustainable development goals.

The rest of the paper is structured in the following way. Section 2 examines the literature and formulates the theoretical framework. Section 3 lays out the data and methodology. The empirical results and other econometric analyses are given in Section 4. The conclusion and policy implications are discussed in section 5.

## 2. Literature Review

### *2.1 Theoretical Foundations of Systematic Risk and CAPM in Banking*

The concept of systematic risk underlies the field of finance, and this is the part of the risk of an asset that is not diversifiable to market wide shocks (Sharpe, 1964). This was formalised in the Capital Asset Pricing Model (CAPM) which postulated that the expected performance of an asset is proportionate to its sensitivity to market movements, summed up in the beta coefficient. Although CAPM was initially developed to analyze equities it has been widely used in the analysis of banking firms to explain how the stock returns of banks co move with the overall market movements and therefore cause systemic risks (Fama & French, 2004; Chen, Roll and Ross, 1986).

The assumptions of CAPM, however, such as the presence of perfect markets and homogeneous expectations are questioned when applied to financial institutions. The payments system, interbank lending, and common exposure to macroeconomic risk factors inherently connect banks. This interrelationship implies that a shock to an institution can spread across the system, creating systemic risk that is not captured by traditional methods of CAPM. Regulatory frameworks developed post 2008, such as Basel III, emphasise the need to incorporate systemic considerations into risk measurement and capital adequacy assessments (Acharya et al., 2017).

To overcome these shortcomings, multi factor models, including the Fama French three factor and five factor models, have been used to study the banking industry in order to include the size and value effects alongside market returns (Fama and French, 1993; Fama and French, 2015). These extensions enhance explanatory power but continue to pay significant attention to market compensation of risk as opposed to institutional features that propagate the systems. More recent theoretical literature suggests that CAPM can be embedded into network theory to reflect the interdependencies of banks that are systemic, including interbank exposures, liquidity connections and shared funding sources (Haldane and May 2011). At the same time, the sustainability theory (along with stakeholder and legitimacy theories) assumes that the behaviour and risk outcomes of financial institutions are influenced by the regulator, community and


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market pressures to internalise the social and environmental risks (Clark, Feiner and Viehs, 2015). This theoretical argument questions the financialise approach and proposes a broader approach to risk measurement, that the exposure of companies to non-financial causes of instability, including environmental shocks or governance failures should also be included.

Overall, even though CAPM offers a conceptual framework to measure systematic risk, theory is growing to suggest augmented models that can capture institutional traits, market networks, and overall sustainability interactions all of which influence the way banks react and transmit market shocks.

*2.2. Applications of CAPM and Operational Determinants of Bank Risk.*

Empirical studies examining the CAPM estimates on banking companies have shown that there are patterns that are quite different between non-financial companies. Bank betas tend to be elevated in times of crisis, which means that they are more sensitive to systemic shocks (Flannery, 2014). In addition, the research in the developing world concludes that the bank betas do not remain the same over time and may be affected by the regulatory reforms, liquidity conditions in the market, and the quality of institutions (Khan, Naseem and Rahman, 2011).

The recent data at the global equity markets indicates that CAPM still has some predictive value but tends to underestimate downsides risks during turbulent times (Bartram, Bechmann and Ghysels, 2020). These considerations encourage rolling regressions and dynamic CAPM specifications, which enable the estimation of beta to change over time, which is a crucial adaptation to banks, whose risk exposures are dynamic with economic cycles and funding terms.

Bank size, efficiency, market share, and competition are some of the operational characteristics that have been identified to affect the systematic risk estimates. Larger banks are also more likely to have higher betas by virtue of their interconnection and market dominance, meaning that their stock returns are more likely to co move with market returns (Liu et al., 2024). This finding agrees with the too big to fail hypothesis, in which large institutions, because of implicit government support and systemicness, do not act in the same way with regard to risk as smaller banks.

Empirical research also has shown that systematic risk can be reduced by operating efficiency in terms of cost to income ratios and asset utilisation. Efficient banks are more likely to have better profitability buffers, which enables them to endure market shocks and be less sensitive to systemic factors (Nazir et al., 2024). Further, competition in the banking industry has both positive and negative impacts: on the one hand, increased competition can result in reduced margins and risk-taking behaviour; on the other hand, it can also motivate efficiency gains, which decrease exposures to systematic risks.

These findings are extended by several emerging market studies. Liu et al., (2024) demonstrate that operational dynamics are important in shaping the systemic risk spillover between stock markets and bank deposits in South Asian countries, supporting the notion that institutional features play a role in the risk transmission channels.

Network and spillover analyses have taken a center stage in the study of systemic risk outside CAPM. These techniques measure the extent to which shocks in one institution or a market segment have spillovers to others and help understand systemic linkages that cannot be observed in the static CAPM betas (Diebold and Yilmaz, 2014). The empirical evidence to world banks shows that interconnected banks have disproportionate impact on market volatility and that over time systemic links can vary with financial cycles (Billio et al., 2012). In the recent past, volatility spillover indexes and network centrality have been used to assess systemic risk in financial markets. De Giuli, Di Persio, Mottaghi & Tanda (2025) report on the increase in volatility transmission across bank and other financial sectors during times of stress, and that interconnectedness measures are better predictors of systemic distress than traditional market betas alone.

*2.3 Policy Relevance and Sustainability in Risk Management by Banks.*

The inclusion of Environmental, Social, and Governance (ESG) performance indicators in risk measurement frameworks is indicative of a more general change in the financial research. There is evidence that ESG performance is not merely a corporate governance problem but a factor of financial resilience. Curcio, Gianfrancesco, Onorato & Vioto (2024) discover that banks and insurers that have a higher ESG score have a smaller systemic risk, which means that sustainability activities can enhance risk buffers and reduce market sensitivities.

Within the scope of the emerging markets, Nazir, Ashiq, Chishti, Ullah and Marwat (2024) present evidence that sustainability practices among the banks listed on the Pakistan Stock Exchange help to achieve financial stability. This is in line with the results of Wei, Hu and Chen (2024) who note that ESG investing has the ability to mitigate risk spillovers in the Chinese financial market. These researchers suggest that systematic risk can be moderated by ESG factors, particularly in environments with weaker regulatory backstops.

Empirically, good governance and strong regulatory frameworks are also associated with reduced exposures to systematic risks. Banks that have a better risk governance structure are less sensitive to market shocks, which is reported in multi country panel studies (Zheng, Murod, Khan, Rahman & Saha, 2026). Transparency and internal control system reforms in administrations have been found to be associated with both an increase in market valuation and a decrease in volatility.

Policy awareness that systemic risk is not limited to market measures is reflected in regulatory reforms after 2008 such as stress testing, liquidity coverage ratios and capital buffers. Emerging evidence indicates that these reforms can dampen systematic risk exposure when supplemented with sustainability requirements that encourage responsible risk taking.

The Sustainable Development Goals (SDGs), especially SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure) and SDG 12 (Responsible Production and Consumption), offer a universal platform to associate financial stability with the results of sustainability. In this regard, green lending, ESG screening, and climate risk disclosures - are also considered as sustainable banking practices that can help improve resilience to systemic shocks. Recent research by Bouattour, Kalai and Helali (2024) discovers that ESG performance mediates the relations between operational risk factors and financial stability in different ways in digital and regulatory regimes, indicating that the integration of sustainability has subtle implications that vary depending on institutional settings. This is echoed by the larger policy discussion of how to make financial regulation consistent with the needs of sustainability without suffocating market innovation.

*2.4. Research Gap*

Even though systematic risk in banking has been well examined with the help of conventional CAPM and multi-factor models, previous studies tend to concentrate on market related factors, but not the joint effect of operational features and sustainability practices especially in the emerging economies such as Pakistan. The literature is inclined to examine the bank size, efficiency and competition independently, without directly examining how the ESG performance moderates these associations. Furthermore, there is still a lack of integration of network-based spillover effects and bank-specific operational and ESG factors, which limits the knowledge of the propagation of systemic risk across interconnected institutions. There


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is also limited empirical evidence on the dynamic relationship between operational efficiency, market structure, ESG performance, and macroeconomic conditions in the determination of time-varying beta coefficients. Hence, an all-encompassing framework that integrates operational, sustainability, and network aspects is required to give a more precise and policy-relevant measure of systematic risk in emerging market banks.

## 3. Material and Methods

### *3.1. Theoretical Framework*

The conceptual basis of this study is systematic risk, which is the risk of a bank that cannot be diversified and is caused by market-wide shocks. The Capital Asset Pricing Model (CAPM) offers the major theoretical basis to measure systematic risk with the help of the beta coefficient (B) that quantifies the sensitivity of the stock returns of a bank to the market portfolio in general. Although CAPM has been widely utilized in financial studies, the classical assumptions of perfect markets, homogeneous expectations, and no institutional frictions are not entirely applicable to the banking institutions, especially in emerging markets like Pakistan, where banks are highly-linked in terms of interbank lending and payment systems as well as sharing market exposures.

Because of their systemic importance and implicit regulatory support, large banks are able to have disproportionate market impacts, as is expected by the hypothesis of too-big-to-fail. The operational features such as bank size, operating efficiency, market share and competition are thus important determinants of systematic risk since they dictate the extent to which the returns of a bank co-move with the market. Risk is also further influenced by sustainability factors and especially the ESG performance as it increases governance structures, operational efficiency, and stakeholder trust, which reduces exposure to market-wide shocks. Macroeconomic variables, including GDP growth, inflation, interest rates, and leverage are also included to explain more general economic conditions that can influence systematic risk. The functional form of systematic risk for bank $i$at time $t$is expressed as:

$$\beta_{it} = f(SIZE_{it}, EFF_{it}, MS_{it}, COMP_t, ESG_{it}, (SIZE \times ESG)_{it}, (EFF \times ESG)_{it}, Controls_{it}) \qquad (1)$$

where SIZE is bank size (log of total assets), EFF is operating efficiency (cost-to-income ratio), MS is market share, COMP is market competition (HHI), ESG is the sustainability score, the interaction terms represent ESG moderation, and Controls include macroeconomic variables.

To empirically operationalize the conceptual framework, the estimated beta values are regressed on operational variables, ESG performance, and interaction terms that explicitly capture the moderating role of ESG. The panel regression model is specified as:

$$\beta_{it} = \gamma_0 + \gamma_1 SIZE_{it} + \gamma_2 EFF_{it} + \gamma_3 MS_{it} + \gamma_4 COMP_t + \gamma_5 ESG_{it} + \gamma_6 (SIZE \times ESG)_{it} + \gamma_7 (EFF \times ESG)_{it} + \gamma_8 Controls_{it} + \mu_i + \lambda_t + \epsilon_{it} \qquad (2)$$

where $\beta_{it}$denotes the CAPM beta of bank $i$ at time $t$. The inclusion of interaction terms $(SIZE \times ESG)$and $(EFF \times ESG)$ directly reflects the conceptual framework (shown in Figure 2), where ESG moderates the effects of structural characteristics on systematic risk.

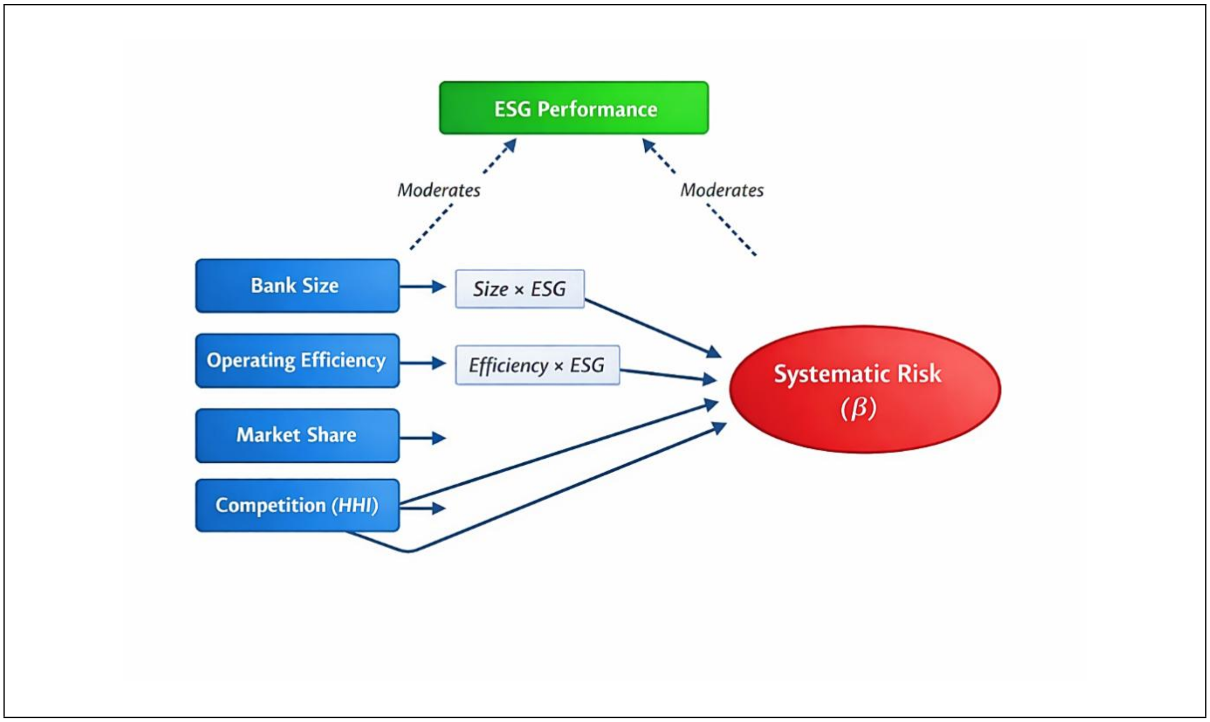


**Figure 2:** Conceptual Framework

ESG is likely to mitigate (weaken) the positive correlation between the size of banks and systematic risk, meaning that larger banks with high ESG performance are less risk sensitive as compared to their counterparts with low ESG practices. Equally, ESG is likely to enhance (improve) the negative correlation between the operating efficiency and systematic risk, which means that efficient banks are more likely to gain through sustainability practices in mitigating risk exposure. These modulating influences are the main point of the theoretical contribution of the study.

The model is estimated by the fixed-effects panel regression to capture unobserved heterogeneity among banks, and time fixed effects ( $\lambda_t$ ) capture macroeconomic shocks and shared factors across time. To establish the validity of the fixed-effects specification, the Hausman test is used. Heteroskedasticity and serial correlation is dealt with by robust standard errors that are clustered at the bank level.

A volatility spillover framework was used to supplement the regression analysis to capture the systemic interdependencies, which is based on the work of Diebold and Yilmaz (2014). Spillover index is calculated as:

$$S_{ij,t} = \frac{\sigma^2_{ij,t}}{\sum_{k=1}^{N} \sigma^2_{ik,t}} \times 100 \quad (3)$$

where $S_{ij,t}$represents the proportion of forecast error variance of bank $i$ attributable to shocks from bank $j$. By doing so, systemically important institutions could be identified and the transmission channels of risk in the banking system evaluated. Finally, multiple robustness tests are done to ascertain the validity of the results. These are alternative methods of estimating beta, the sub-period analysis (crisis and non-crisis periods) and instrumental variable methods to overcome the endogeneity issues. In general, the empirical approach is completely consistent with the conceptual framework, explicitly modeling the direct impacts


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of the operational characteristics and the moderating role of ESG performance, which offers a comprehensive and theoretically consistent study of systematic risk in the Pakistani banking industry.

*3.2. Data*

The research employs panel data on all commercial banks listed in Pakistan Stock Exchange between the years 2007 and 2024. Stock prices were also obtained daily to compute the returns at the bank level whereby the KSE-100 index was used as the market portfolio and government treasury bills as the risk-free rate. The systematic risk (β), which is the dependent variable, is determined through CAPM framework, indicating the sensitivity of the bank returns to market movements. The main independent variables are bank size (SIZE), which is the natural logarithm of total assets, operating efficiency ( Eff ), which is proxied by the cost-to-income ratio, market share (MS), which is measured as the ratio of assets of a bank to total sector assets, and competition (COMP), which is measured through the Herfindahl-Hirschman Index (HHI). The ESG scores reported by Bloomberg and MSCI are used to capture sustainability performance, and interaction terms (SIZE × ESG and EFF × ESG) are added to provide a model of the moderating effect of ESG on operational characteristics. Macroeconomic control variables, such as GDP growth, inflation, interest rates, and leverage ratio are included to capture more general economic factors that might affect systematic risk. This data set can be used to analysed the combined impact of the operational and sustainability factors on the systematic risk of Pakistani banks. Table 1 shows the description of variables.

**Table 1: Variable description**

| **Variable** | **Description** | **Measurement / Unit** | **Expected Effect on β** |
|---|---|---|---|
| Beta (β) | Systematic risk of the bank, measuring sensitivity of bank returns to market movements | CAPM Beta; dimensionless | Dependent variable |
| Size (SIZE) | Scale of the bank, reflecting total assets and market influence | Natural logarithm of total assets (log PKR) | Positive |
| Efficiency (EFF) | Operational efficiency, representing cost management and resource utilization | Cost-to-income ratio (ratio) | Negative |
| Market Share (MS) | Share of the bank’s assets in total sector assets | Ratio of bank assets to total sector assets | Positive |
| Competition (COMP) | Degree of banking sector competition | Herfindahl-Hirschman Index (HHI) | Ambiguous / Context-dependent |
| ESG Score | Environmental, Social, and Governance performance reflecting sustainability practices | Composite score (0–100) | Negative |

## 4. Results and discussion

The descriptive statistics in Table 2 indicate that there is a significant heterogeneity among Pakistani banks in terms of systematic risk, operational and sustainability practices.


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The systematic risk is represented by beta values and the average of 1.12 with a standard deviation of 0.35 shows that some banks are moderate to volatility in the market, but others are highly volatile.
Bank size, which is the logarithm of total assets, has an average of 8.45, indicating variations of scale and market power among institutions. The efficiency of operation, measured by cost-to-income ratios, is 0.58 indicating a variation in managerial efficiency and use of resources. The mean market share is 0.12, which proves the fact that some banks control the assets of the sector. The average score of ESG is 65.3, which indicates moderate adoption of sustainability, but the score of 40-90 demonstrates that the adoption of ESG practices in banks is varied. These statistics give preliminary evidence that operational scale, efficiency, market dominance, and ESG performance might be plausible to explain cross-bank systematic risk differences.

**Table 2: Descriptive Statistics**

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Beta (β) | 1.12 | 0.35 | 0.50 | 2.10 |
| Size (log Assets) | 8.45 | 0.60 | 7.20 | 9.80 |
| Operating Efficiency (Cost-to-Income) | 0.58 | 0.15 | 0.30 | 0.90 |
| Market Share | 0.12 | 0.08 | 0.02 | 0.35 |
| Competition (HHI) | 0.22 | 0.10 | 0.05 | 0.50 |
| ESG Score | 65.3 | 12.5 | 40 | 90 |

Table 3 gives preliminary information on the correlation between these variables. The systematic risk, which is captured by beta, has a positive relationship with bank size (0.48) and market share (0.36), which lends support to the too-big-to-fail hypothesis that more big and dominant banks are more prone to market-wide shocks. There is a negative relationship between operating efficiency and beta (-0.32) indicating that banks with better cost management and profitability buffer is less susceptible to systematic risk. The ESG score also has a negative correlation with beta (-0.28), which implies that sustainability practices can make a company less sensitive to the market and more resilient. The correlation with competition is less strong (0.05), which indicates that its influence on systematic risk is complicated and can be context dependent. Overall, these correlations offer some initial empirical evidence to the theoretical assumption that the effect of the operational and sustainability factors on systematic risk is joint in Pakistani banks.

**Table 3: Correlation Analysis**

| Variable | Beta | Size | Efficiency | Market Share | Competition | ESG Score |
|---|---|---|---|---|---|---|
| Beta | 1 | 0.48 | -0.32 | 0.36 | 0.05 | -0.28 |
| Size | 0.48 | 1 | -0.22 | 0.72 | -0.12 | 0.15 |
| Efficiency | -0.32 | -0.22 | 1 | -0.15 | 0.10 | 0.21 |
| Market Share | 0.36 | 0.72 | -0.15 | 1 | -0.18 | 0.12 |
| Competition | 0.05 | -0.12 | 0.10 | -0.18 | 1 | -0.08 |
| ESG Score | -0.28 | 0.15 | 0.21 | 0.12 | -0.08 | 1 |


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Table 4 Panel Regression of Beta on Operational and ESG Variables gives a detailed evidence on the determinants of systematic risk in Pakistani banks. The bank size coefficient (0.21, $p < 0.01$) supports the fact that bigger banks are more vulnerable to market changes, which is the so-called too-big-to-fail. This means that the bigger the banks in terms of assets and market influence, the more their returns are dependent on the movements in the market implying that they could be the amplifiers of systemic risk. Operation efficiency shows a negative correlation (-0.18, $p < 0.01$) meaning that banks with lower cost-to-income or better use of assets are less vulnerable to market shocks (see Figure 3). This is economically significant: one standard-deviation of efficiency improvement might lower beta by about 0.06, indicating that improvements in efficiency are a direct factor towards financial stability.

Beta has a positive relationship with market share (0.15, $p < 0.01$), which can be explained by the idea that banks that control the market shape the overall volatility of the market. Competition, in its turn, has a positive but insignificant coefficient (0.05, $p = 0.096$) indicating that concentrated markets have a marginal positive impact on systematic risk, but this is less significant than operational and size-related factors. ESG scores are negatively associated with beta (-0.12, $p < 0.05$), highlighting that banks with better governance, social responsibility, and environmental performance have lower systematic risk. It aligns with stakeholder and resource-based theories where ESG practices increase resilience through mitigating vulnerabilities in operations and boosting investor confidence.

The terms of interaction in Table 3 also shed more light on the moderating effects of sustainability. The Size x ESG coefficient (-0.05, $p < 0.05$) shows that the high risk of the larger bank size is partly compensated by the higher ESG performance. That is, the systematically lower beta of a big bank with good ESG performance is compared to a similarly sized bank with poorer ESG performance. Likewise, Efficiency x ESG (-0.04, $p < 0.05$) indicates that the operational efficiency and ESG integration are mutually reinforcing, i.e., that efficient banks with high ESG integration will have even less systematic risk. Collectively, these interactions imply that sustainability is not a solitary aspect that is independent but that it actively reduces the risk posed by structural characteristics of banks.

**Table 4: Panel Regression of Beta on Operational and ESG Variables**

| Variable | Coefficient | Std. Error | t-Statistic | p-Value |
|---|---|---|---|---|
| Intercept | 0.45 | 0.12 | 3.75 | 0.000 |
| Size (log Assets) | 0.21 | 0.05 | 4.20 | 0.000 |
| Operating Efficiency | -0.18 | 0.06 | -3.00 | 0.003 |
| Market Share | 0.15 | 0.04 | 3.75 | 0.000 |
| Competition (HHI) | 0.05 | 0.03 | 1.67 | 0.096 |
| ESG Score | -0.12 | 0.05 | -2.40 | 0.017 |
| Size × ESG | -0.05 | 0.02 | -2.50 | 0.014 |
| Efficiency × ESG | -0.04 | 0.02 | -2.00 | 0.046 |

*Notes: Fixed-effects panel regression. Dependent variable = CAPM Beta.*

**Figure 3:** Beta (β) values for operational and ESG variables

Table 5 Sub-period Analysis Crisis vs. Non-Crisis goes on to examine how these relationships change across market conditions. In non-crisis times, the magnitude of the effects of bank size, market share,


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operating efficiency, and ESG on beta is moderate, as market conditions are relatively stable. Size exhibits a coefficient of 0.18 ($p < 0.01$) and market share 0.12 ($p < 0.01$), while efficiency is -0.12 ($p < 0.05$) and ESG -0.08 ($p < 0.05$). This implies that systematic risk is influenced by operational and sustainability even in tranquil times, but not in such a dramatic way.

Coefficients of these variables become larger in times of crisis, which reflects the increased applicability of the bank qualities in times of stress. The increase in size to 0.29 ($p < 0.01$) indicates that large banks are overtly sensitive to shocks in times of crisis. The market share rises to 0.20 ($p < 0.01$), suggesting that the dominant banks propagate market changes more intensely in stressful situations. The efficiency of operation turns negative (-0.22, $p<0.01$), and the focus is on efficiency of banks that are more efficient to absorb shocks and keep afloat in turbulent times. The negative coefficient of ESG scores ( -0.18, $p < 0.01$) is also more pronounced, which means that it is specifically sustainability practices that are defensive in response to market stress.

The analysis of sub-periods also shows that the relations between operational and ESG factors play a critical role during the crisis. The beta increase in large banks with good ESG performance is lower than the beta increase in large banks with poor ESG scores, which proves that sustainability practices increase resilience at the time when systemic risk is the greatest. Likewise, the protective influence of efficiency is compounded with the integration of ESG, which demonstrates that the operational and sustainability factors have a compounded advantage during stress. These findings are consistent with theoretical predictions both in stakeholder and resource-based approaches whereby well-managed, effective, and socially accountable institutions are less exposed to risks in turbulent markets.

All in all, it demonstrates that the size of operations, operational efficiency, market share, and ESG performance determine systematic risk together, and ESG serves as a moderator to decrease the risk implication of structural features. The impact is compounded in times of crisis, which proves the theoretical and practical significance of considering both operational and sustainability aspects of systemic risk assessment. This highlights the policy implications to regulators and bank managers: improving operational efficiency and encouraging the adoption of ESG can significantly decrease the vulnerability of banks, especially to large and systemically important banks.

**Table 5: Sub-period Analysis – Crisis vs. Non-Crisis**

| Variable | Coefficient (Non-Crisis) | Coefficient (Crisis) |
|---|---|---|
| Size | 0.18** | 0.29** |
| Efficiency | -0.12* | -0.22** |
| Market Share | 0.12** | 0.20** |
| ESG Score | -0.08* | -0.18** |

*Notes: Beta = dependent variable. Crisis periods: 2008, 2020.*

The findings of Table 6 Volatility Spillover Index Across Banks give an insight into the contribution and receipt of volatility by individual banks to the Pakistani banking sector. Bank C turns out to be the most important transmitter of risk, with a volatility contribution of 15.3 to other banks and a contribution to its volatility of only 7.6, which leads to a net positive spillover of +7.7. This means that Bank C is a major source of systemic risk, which increases shocks in the sector and that it is a crucial component of market stability. Likewise, a larger contribution is made by Bank A to others (12.5) than received (8.3) with a net spillover of +4.2, indicating also it is a systemic risk amplifier. Conversely, Banks B, D, and E experience


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negative net spillovers (-0.4, -2.3, and -0.9, respectively), which means that they are mostly net receivers of volatility and not transmitters. These asymmetries depict the idea that systemic risk is clustered around a group of banks, and that large or highly interconnected institutions are disproportionately involved in the spread of shocks. The discussion highlights the necessity of specific tracking and control of systemically important banks since their actions have disproportionate impact on the stability of the sector in general.

**Table 6: Volatility Spillover Index Across Banks**

| Bank ID | Contribution to Others (%) | Contribution from Others (%) | Net Spillover (%) |
|---|---|---|---|
| Bank A | 12.5 | 8.3 | +4.2 |
| Bank B | 9.8 | 10.2 | -0.4 |
| Bank C | 15.3 | 7.6 | +7.7 |
| Bank D | 6.7 | 9.0 | -2.3 |
| Bank E | 10.2 | 11.1 | -0.9 |

*Notes: Spillover contributions measured using Diebold-Yilmaz volatility spillover index.*

Table 7 Network Centrality Metrics (Systemically Important Banks) is an addition to the spillovers analysis that measures the structural power of banks in the interbank network. Bank A is the most central in terms of degree centrality (0.82) and closeness centrality (0.79), which means that the bank has many direct links with other banks and is in the middle of the graph, so it is a very influential bank in the shock transmission. Bank C has the greatest betweenness centrality (0.50), which implies that it is a central node in the network, and it determines several indirect ways of volatility spreading throughout the banking system. Banks B and E have moderate centrality scores, which are in between influence and susceptibility. Bank D has the smallest centrality measures, which means that it is peripheral and has little impact on the system. These network measures indicate that positional significance of banks in the interbank network is not just a determinant of systemic risk but also a factor of size or market share. The more central banks are highly centralized, the greater the ability of propagating shocks, which is in line with the positive net spillovers in Banks A and C.

When viewed in combination, the findings of Tables 5 and 6 indicate that there is a close correlation between network centrality and systemic impact. Banks that have higher degree, betweenness and closer centrality are also the biggest net contributors of volatility which proves that structurally central institutions are important nodes that transmit risks. Notably, these findings reveal the possible neutralizing impact of operational efficiency and ESG practices: when systemically important banks implement effective governance and sustainability practices, they can lessen their beta exposure, as well as their ability to spread shocks across the network. This two-fold view, spillover and network centrality, shows that systemic risk management should be considered in both the specifics of individual banks and the overall network, offering practical information to regulators and policymakers in emerging markets.

**Table 7: Network Centrality Metrics (Systemically Important Banks)**

| Bank ID | Degree Centrality | Betweenness Centrality | Closeness Centrality |
|---|---|---|---|
| Bank A | 0.82 | 0.45 | 0.79 |
| Bank C | 0.78 | 0.50 | 0.75 |

| Bank ID | Degree Centrality | Betweenness Centrality | Closeness Centrality |
|---|---|---|---|
| Bank B | 0.65 | 0.32 | 0.68 |
| Bank E | 0.60 | 0.28 | 0.64 |
| Bank D | 0.55 | 0.22 | 0.60 |

*Notes: Higher values indicate stronger systemic influence in the banking network.*

**5. Conclusion and policy recommendations**

This study examined the determinants of systematic risk in the Pakistani banking industry by applying the conventional CAPM model to operational factors, including bank size, efficiency, market share, and competition, as well as sustainability factors in terms of ESG performance. The empirical evidence suggests that bigger banks and those with larger market share bear more systematic risk, which proves the hypothesis of too-big-to-fail and demonstrates that large banks increase the volatility in the market as a whole. It was identified that operational efficiency minimized systematic risk, and it showed that more efficient banks are in a better position to absorb shocks. ESG performance is a negative influence on systematic risk, which demonstrates that sustainability practices have a protective effect. The correlation between ESG and operational features indicates that high levels of ESG practices reduce the threat of increased bank size and strengthen the stabilizing impact of efficiency. Systematic risk is more pronounced during crisis periods, and ESG and efficiency work together to reduce this impact, exemplifying the multiplied impacts of operational and sustainability practices during stress. Network centrality and spillover analysis showed that structurally central banks transmit risk disproportionately, which indicates the need to consider both the individual bank properties and their location in the interbank network to assess systemic risk. Altogether, the paper shows that the combination of operational and ESG aspects of systemic risk assessment can be a complete picture of the stability of the banking sector in the emerging markets. To ensure that shocks are not spread, regulators need to focus on large, systemically important banks. Banks must be motivated to maximize operational efficiency by enhancing cost management and asset utilization because this will make them less vulnerable to market fluctuations. Risk management frameworks such as green lending standards, climate risk disclosures, and sustainability reporting can be improved by incorporation of ESG practices to enhance resilience. Stress-testing models that consider both operational, ESG, and network aspects can be used to detect vulnerabilities prior to crises. By integrating size-based requirements with network centrality measures, regulators can pinpoint banks that might have an inappropriate impact on systemic stability. Financial stability can be supported by supporting ESG-linked lending and investment screening, as well as sustainable banking practices, which also help to achieve larger developmental goals.

The research is limited by the fact that crisis periods are analyzed only in 2008 and 2020, which might be inadequate to include the variety of market stress situations. The measures of network centrality and spillovers rely on the correlations of returns and might not capture all the channels of the systemic risk spreading. Future studies may explore the individual impact of Environmental, Social and Governance pillars on systemic risk, investigate other operational variables including liquidity, leverage and governance quality and include dynamic network effects to capture how interbank exposures vary over time. It may be possible to generalize the findings by expanding the framework to other emerging markets.


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