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# The Impact of Sustainable Lending on Banks' Performance Using Machine-Learning Method: An International Evidence

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**Abstract.** This study investigates the impact of sustainable lending, represented by sustainability-linked loans and green loans, on the financial performance of banks in 14 emerging and developed markets during 2013-2022. Bank performance is measured by profitability, management efficiency, and asset quality. Panel data regression and Support Vector Regression (SVR) approaches are employed to analyze the data and compare the results. The findings reveal that sustainability-linked loans have a significant negative effect on profitability (return on equity) and management efficiency (cost-to-income ratio), while green loans exhibit a positive effect on profitability partially through non-interest income, but a negative impact on return on equity and asset quality. Macroeconomic factors, including domestic credit to the private sector, GDP, and exchange rate, are also identified as determinants of bank performance. The results indicate that the SVR model performs better in prediction compared to the panel regression model. The study contributes to the literature by providing empirical evidence on the impact of sustainable lending on bank performance and employing machine learning techniques. Practical implications for policymakers and financial institutions are discussed, highlighting the need for a better understanding of sustainable finance practices and their effects on bank performance.

**Keywords:** Banks' Performance, Emerging and Developed Markets; Green loans; Machine-Learning Method; Support Vector Regression; Sustainability Linked Loans; Sustainable lending.

# 1. Introduction

In recent years, sustainable finance has become growingly significant in the financial market because of most financial institutions have adopted new financial instruments to enhance their financial performance, which are in the form of green, social, sustainable, and sustainability-linked bonds and loans, as a complement to public funding. The terms 'green finance' and 'sustainable finance' connect with an interfering district of issues interrelated to each other. A distinction can be drawn between manners to sustainable finance that attentive on a broad scale environmental, social, and governance factors, and those that take a narrower level, 'green finance' one interested only in environmental issues. Therefore, green finance is an inherent element of sustainable finance. While social finance supports actions addressing a specific social issue (United Nations Environment Program (UNEP), 2016).

Notably, sustainability-linked finance mobilizes capital to boost the borrower's improved environmental, social, and governance performance and to achieve sustainability goals via pricing incentives. The most popular tools instruments for this type of financing include sustainability-linked loans (SLLs) and sustainability-linked bonds (SLBs). One of the bond instruments that the financial characteristics can vary relying on the fulfillment of sustainability goals is SLBs. While SLLs are financial products that relate the cost of financing to performance versus determined sustainability standards. This indicates that sustainability practice is becoming a widespread phenomenon around the world. It's noteworthy that over the last several years, sustainable finance has become increasingly significant in the realm of global financial decision-making and the financial market. Under this importance, interest to study in the relation between sustainable financial activities and financial performance has been increased between academics and investors (Siew et al., 2013; Jyoti and Khanna, 2021; Pham et al., 2021). Consequently, most financial institutions have adopted ESG concerns as an important strategy to enhance their financial performance. Some studies examined the relationship between sustainability practices and financial performance (Nizam et al., 2011). Empirical studies discovered a positive link between financial performance and social responsibility (Belasri, et al., 2020; Nizam et al., 2011) good governance (Affes, and Jarboui, 2023), and environmental sustainability (Nizam et al., 2011).

Nevertheless, other research revealed reverse evidence: financial performance has a negative relation with social score (Buallay, 2019; Jyoti and Khanna, 2021) managerial ownership (Alkurdi et al., 2021), or no strong relationship with sustainability practices (Siew et al., 2013). From published literature, it is exciting that the research available until the current display mixed outcomes; positive, negative, and non- crucial, making it even more challenging to deduce (Gillan, et al., 2021). Despite the promising evidence of the corporate ESG performance and its influence on financial performance across various business sectors (El Ghoul et al., 2011; Nizam et al., 2011; Fu and Li, 2023), the findings from the banking sector remain limited and inconclusive (Komarnicka and Komarnicki, 2022). In this context, there is a paucity of studies that may be able to provide evidence of sustainability linked finance, compared by green finance and their impact on banks' performance. Therefore, this study seeks to fill a gap in the sustainability literature in emerging and developed economies by addressing the debate over whether using sustainability linked finance compared to other instruments would improve, reduce, or have no impact on financial performance, where this study focuses on the banking sector to comprehend the role of this sector in promoting sustainable finance within these nations. The following graphs that show the development of sustainability linked loans and green loans for 14 countries in emerging and developed markets during from 2013 to 2022, as shown in figure 1 & 2:

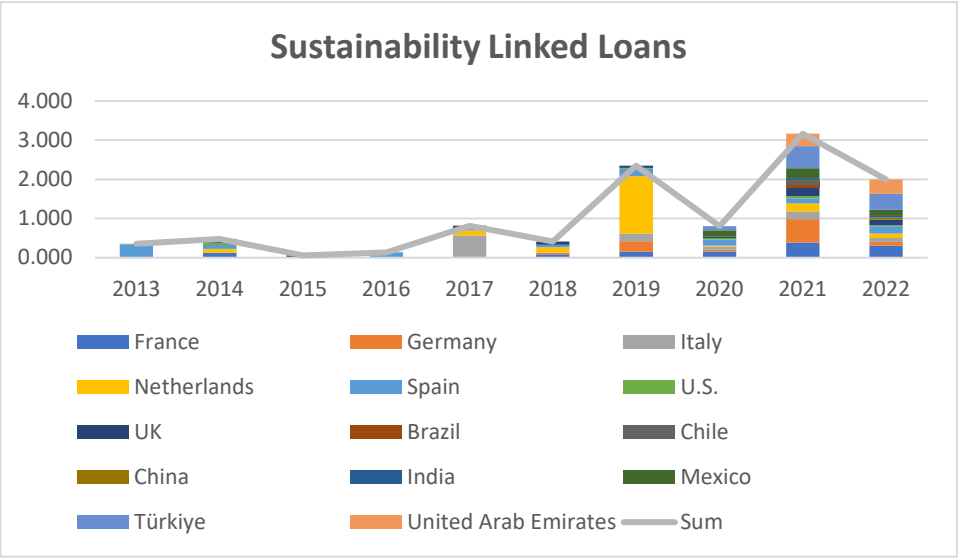


Fig.1: Sustainability linked loans issuance in markets.

Source: Prepared by Researcher.

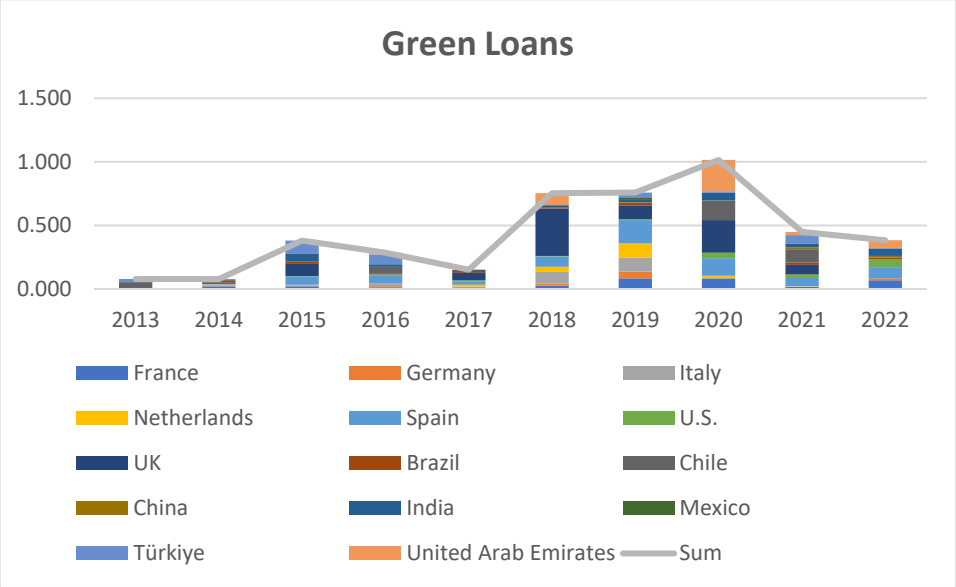


Fig.2: Green loans issuance in markets.

Source: Prepared by Researcher.

It is obvious that there has been an increase in the use of sustainability linked loans in markets over the last several years, as shown in figure 1. It indicates that the countries are trying to endeavor for a sustainable economy. Also, figure 2 points out that there has been a development in the investments of green loans for 14 countries during 2013-2022. These countries use green instruments to seek a better future through environmental projects but exclude social and economic aspects. In this context, bank lending is the most important function because it results in return for the bank but also exposes it to credit risk and so it affects the bank's performance. Therefore, this study focuses on a novel form of debt financing – sustainability linked loans compared to one of green finance instruments and seeks to check whether there is a significant effect of the sustainability linked finance compared to one of green finance instruments on financial performance for the banking sector in 14 countries, focusing on emerging and developed markets. Thus, this study's objective is to investigate the impact of Sustainable Lending on Banks' Performance to fulfill partially an existing research gap regarding: (a) applying to

14 countries all over the world divided between developing and developed countries, (b) measuring sustainable lending with different metrics and (c) utilizing the methodology of machine learning with comparison to the traditional panel regression analysis.

Further this study seeks to identify the significant variables that may have an impact on banks' performance, it considers both the market characteristics and macroeconomic variables. The contributions of my study are as follows. Firstly, previous research on the relationship between ESG and financial performance has mainly focused on companies, with less attention paid to sustainable finance impact on the banking sector. This study focused on developing and developed countries as research samples to verify this relationship, thus expanding the existing literature. Second, this study is among the first to use sustainable linked finance compared to other instruments to investigate the impact of sustainable lending on banks' performance. Third, this study aims to identify significant variables that may have an impact on banks' performance. Fourth, this study employs panel data regression and Support Vector Regression.

In view of the above discussions, this study is among the first to focus on sustainable linked finance compared to one of green finance instruments and to investigate the effect of these instruments on banks' performance for 14 countries over 9 years. Further, this study explores the determinants of banks' performance in these markets and employs machine learning techniques. In brief, this study tries to answer the following questions:

- Does sustainability linked loans affect financial performance in markets?
- Do green loans affect financial performance in markets?
- Do macroeconomics factors and market characteristics affect financial performance in markets?

The findings indicate a significant negative effect of sustainability linked loans on profitability and the management efficiency, indicating the sustainability linked loans decrease return on equity and increase cost to income ratio. Simultaneously, the results show that green loans have a negative effect on return on equity and a positive impact on asset quality and profitability partially. In addition, the outcomes also reveal that macroeconomic factors play an important role and are important determinants of banks' performance. In this study, data analysis with panel data and conduct a robustness check by using two measures of sustainable lending simultaneously resulted in robust and consistent findings. Furthermore, the results reveal that the SVR model performs better in prediction compared to the regression model.

Remarkably, the results have practical implications for investors and policymakers to understand the relation better, arouse institutions to execute sustainable financial activities. This study may be expanded by conducting more studies to focus on the effect of sustainable finance on banking risks. This study is organized as follows: section 2 reviews the literature and hypothesis, while section 3 presents the data and variables development. Section 4 presents the methodology used. Section 5 highlights an analysis of the results of the empirical study while section 6 concludes and makes recommendations for further research.

# 2. Related Literature and Research Hypotheses

This section tries to present some of the previous work that has been conducted in three fields: a) review of sustainability practices and Application Difference in financial institutions; b) Impacts of the ESG aspects on financial performance by result difference, and c) Macroeconomic Factors and Financial Performance.

## 2.1. Review of Sustainability Practices and Application Difference

Some studies seek to assess the impact of sustainability practice on the business financial situation in countries (Nizam et al., 2011; Pham et al., 2021; Shahzad, 2023). Regarding the relationship between the ESG factors and financial performance, both as a group and separately, this field has attracted the interest of academics to examine this issue where these aspects serve as tangible appearances of

sustainable development within institutions (Siew et al., 2013; Buallay, 2019; Jyoti and Khanna, 2021; Feng et al., 2022; Rahi et al., 2022; Fu and Li, 2023).

Nizam et al. (2011) address what and how social and environmental sustainability impacts on the financial performance of the banking sector globally using cross-sectional and threshold regressions analysis of 713 banks in 75 countries during 2013 to 2015. Nizam et al. (2011) finds that access to finance positively impacts on banks' performance through loan growth and management quality. Interestingly, Pham et al. (2021) analyze the impact of sustainability practices on financial performance of 116 listed companies in Sweden using accounting and financial data such as return on assets, return on equity, and return on capital, earnings yield, and Tobin's Q in 2019. Pham et al. (2021) reveal that there is a positive relationship between corporate sustainability and financial performance.

In this regard, Shahzad (2023) assures the significant impact of sustainable investment on the bank's performance in Pakistan during the period of 2013 to 2022. Shahzad (2023) finds that social factors have a positive impact on return on equity and the earnings per share, while the governance scores have a positive on EPS during this period. Also, Shahzad provides evidence that the return on equity and assets increased after implementing environmental investments in banks.

Most of previous research has been applied the sustainability practices and ESG factors to only one country (e.g., Balatbat and Carmichael, 2013; Carmichael, 2013; Alkurdi et al., 2021; Pham et al., 2021; Jyoti and Khanna, 2021; Feng et al., 2022; Fu and Li, 2023; Affes and Jarboui, 2023; Shahzad, 2023). Some others apply to 75 countries (e.g., Nizam et al., 2011) or European Union countries (e.g., Buallay, 2019) or Nordic region (e.g., Rahi et al., 2022).

## 2.2. Impacts of the ESG Aspects on Financial Performance by Result Difference

Some studies focus on examining the relation between the three ESG aspects and financial performance and show that these dimensions enhance financial performance (Buallay, 2019; Feng et al., 2022; Fu and Li, 2023). Other studies revealed that these factors have a negative impact on performance (Jyoti and Khanna, 2021), or no strong relationship with performance (Siew et al., 2013). In this regard, the empirical findings are mixed (Rahi, Akter, and Johansson, 2022). And some of these studies are briefly discussed as follows.

Interestingly, Buallay (2019) indicated that the ESG has a significant positive effect on performance, measured by return on assets, return on equity and Tobin's Q for 235 listed banks in the European Union countries from 2007 to 2016. However, the relation between banks' performance and sustainability reporting varies if measured individually; the environmental disclosure has a positive impact on the ROA and TQ. Although social responsibility disclosure is negatively impacting on performance, governance disclosure has a positive effect on the TQ and a negative effect on other measures of performance. Additionally, Feng et al. (2022) find that their evidence ESG ratings are negatively associated with stock-price crash risk of listed firms in China from 2009 to 2020. Similarly, Fu and Li (2023) empirically result indicated that ESG has a significant positive effect on corporate financial performance, and digital transformation drives this enhancing impact of listed companies in China during the period 2015 to 2021. Fu and Li (2023) find that the positive effect of ESG differs depending on ownership type, country, and level of pollution. Affes and Jarboui (2023) addresses the effect of the implementation of effective corporate governance on the financial performance for 160 companies in the UK during 2005-2018. They find that there exists a positive relation between good corporate governance and firm performance, measured by return on equity.

Nevertheless, Jyoti and Khanna (2021) analyze the effect of the sustainability performance on the financial performance of service sector listed firms in India during from 2014 to 2018. The authors found evidence that the ESG combined scores have an eminent adverse impact on return on assets (ROA) and return on capital, but the effect of the social score has a significant negative influence on the return on equity. Additionally, Alkurdi et al. (2021) finds that there exists a significant positive relationship between institutional ownership and financial performance as measured by ROA and Tobin's Q (TQ)

for firms listed on the Amman Stock Exchange from 2012 to 2018 in the Jordan. While they reveal that there exists a negative relationship between managerial ownership and ROA, there is no relation with TQ. As highlighted by Rahi et al. (2022), whether sustainability influences financial performance for 39 financial companies in the Nordic region during 2015–2019. They conclude that there is a negative relationship between ESG practices and return on invested capital, return on equity and earnings per share. While they reveal that there is a positive link between governance and ROA.

While Siew, Balatbat, and Carmichael (2013) explore the effect of issuing reports relating to ESG activities on the financial performance for the 44 listed construction companies in Australia. Results show that the firms that issue non-financial reports have better financial performance than those that do not, although the correlation between financial performance and ESG scores is not strong. This reflects the nascent nature of the research field on sustainable finance, illustrating strong research importance for more research to investigate the impact of sustainable lending on banks' performance. According to the literature review and problem statement discussed above, this study aims at testing the following hypothesis:

H1: Financial performance is significantly driven by sustainable lending in sustainable debt markets.

Hypothesis testing criteria:

HO1: There is no significant effect of sustainable lending on financial performance in markets.

HA1: There is a significant effect of sustainable lending on financial performance in markets.

## 2.3. Macroeconomic Factors and Financial Performance

Regarding the determinants of banks' performance, most of the studies in the literature have revealed that there are positive or negative effects of macroeconomic on financial performance according to countries and periods (Kiganda, 2014; Egbunike and Okerekeoti, 2018; Haider et al., 2018; Suseno, 2020; Arzova and Sahin, 2023; and Mitra, Gupta, and Gupta, 2023).

The results of the previous evidence are mixed, where some studies found there is no significant effect for ESG on financial performance (e.g., Kiganda, 2014; Egbunike and Okerekeoti ,2018; Suseno, 2020). Kiganda (2014) finds that macroeconomic factors including GDP, inflation, and exchange rate have insignificant effect on bank profitability in Kenya with Equity bank during 2008- 2012. In this context, Kiganda (2014) supported by Suseno (2020) in Indonesia, which show that the macroeconomic factors had no significant impact on financial performance for 17 listed firms of the consumer goods sector in Indonesia during 2012 – 2018. Egbunike and Okerekeoti (2018) finds no significant impact for interest rate and exchange rate on ROA for consumer goods sector firms listed in Nigeria during 2011–2017.

Whereas other studies revealed that there is a significant effect for ESG on financial performance (e.g., Haider et al., 2018; Egbunike and Okerekeoti, 2018; Arzova and Sahin, 2023; and Mitra et al., 2023). Haider et al. (2018) reveal that there exists a negative relation between macroeconomic factors including inflation, interest rate, GDP growth rate, and exchange rate and financial performance, as measured by return on equity, return on assets, and gross profit margin for listed companies in Pakistan during 2007- 2016. But they find that inflation has a positive relationship with return on equity only. Egbunike and Okerekeoti (2018) Also finds a significant effect for inflation rate and GDP growth rate on ROA for consumer goods sector firms listed in Nigeria during 2011–2017. While Arzova and Sahin (2023) suggest that macroeconomic factors including inflation, foreign direct investment, and GDP increase bank profitability for 17 countries during 2011-2020. Mitra et al. (2023) assure that financial performance has a positive relationship with macroeconomic factors of Indian manufacturing companies during 2004-2022. The current study examines the impact of macroeconomic and market characteristics on financial performance. Therefore, this study proposed the following hypothesis:

H2: Banks' performance is significantly driven by macroeconomic factors in markets. Hypothesis testing criteria:

HO2: There is no significant effect of macroeconomic factors on banks' performance in markets.

HA2: There is a significant effect of macroeconomic factors on banks' performance in markets.

In this context, there is a paucity of studies that may be able to provide evidence of sustainability linked finance, compared by green finance and their impact on banks' performance. Therefore, this study investigated whether sustainability linked loans compared to green loans influence the financial performance of the banking sector in emerging and developed markets. Further this study seeks to identify the significant variables that may have an impact on banks' performance, it considers both the market characteristics and macroeconomic variables.

# 3. Research Methodology

## 3.1. Data sources

The sample includes seventy observations in 14 countries, chosen as the most representative developed and emerging markets according to data availability from 2013 up to 2022. The counties represent developed markets (France, Germany, Italy, Netherlands, Spain, U.S., and UK) and emerging markets (Brazil, Chile, China, India, Mexico, Turkey, and UAE). To explore the relationship between sustainable lending and banks' performance over the study period, this study employs panel data regression and Support Vector Regression. The data are obtained from several sources, including the Institute of International Finance (IIF), the International Monetary Fund (IMF) and the World Development Indicators (WDI) database of the World Bank.

## 3.2. Variable's Definition:

## 3.3. Dependent Variable: Financial Performance

Financial performance is assessed based on several factors such as profitability, liquidity, efficiency, and asset quality, et... Following the literature, this study measures the banks' performance by profitability, management efficiency, and asset quality.

## 3.4. Independent Variable: Sustainable Lending

Prior studies (Berry-Stolzle et al., 2010; and Eling and Jia, 2019) have indicated that sustainable lending represents sustainable linked loans and green finance. Consequently, this study uses sustainable linked loans and green finance as a proxy of sustainable lending to assess its impact on financial performance.

## 3.5. Control Variables

To control other factors that could affect the empirical findings, this study selected five indicators identified from previous research as control variables (Albertazzi and Gambacorta, 2009; and Mirzaei et al., 2013). Consequently, this study includes the following variables: domestic credit to private sector by banks, gross domestic product, inflation of GDP deflator, real effective exchange rate, and market capitalization of listed domestic companies as determinants of financial performance. Table 1 presents description of the study variables, as follows:

Table 1: Description of variables used for testing hypotheses.

| Variable | Abbreviation |
|---|---|
| Sustainability-linked loans % of GDP | SL |
| Green loans of GDP ratio | GL |
| Return of Equity | ROE |
| Net Interest Income Ratio | NII |

| | |
|---|---|
| Cost to Income Ratio | CI |
| The share of non-performing loans to total loans | NPL |
| Domestic credit to private sector by banks (% of GDP) | DB |
| GDP (constant 2015 US$) | GDP |
| Inflation, GDP deflator (annual %) | INF_GDPDEF |
| Market capitalization of listed domestic companies (% of GDP) | M_capital |
| Real effective exchange rate index (2010 = 100) | Exc |

Source: Prepared by Researcher.

### 3.6. Research Models

In this section, an overview of the methodology that was employed will be given. The models were estimated using EViews and Statistica software.

### 3.7. Panel Regression Analysis

This study employs ordinary least squares regression analysis and two panel data models (fixed and random effects models) to assess the impact of sustainable lending on banks' performance. According to literature review, banks' performance can be predicted by several factors as follows:

$$(\widehat{NPL})_{it} = \alpha_0 + \beta_1 SL_{it} + \beta_2 DB_{it} + \beta_3 GDP_{it} + +\beta_4 INF\_GDPDEF_{it} + \beta_5 M\_CAPITAL_{it} + \beta_6 Exc_{it} + e_{it} \quad (1)$$

$$(\widehat{CI})_{it} = \alpha_0 + \beta_1 SL_{it} + \beta_2 DB_{it} + \beta_3 GDP_{it} + \beta_4 INF\_GDPDEF_{it} + \beta_5 M\_CAPITAL_{it} + \beta_6 Exc_{it} + e_{it} \quad (2)$$

$$(\widehat{NII})_{it} = \alpha_0 + \beta_1 SL_{it} + \beta_2 DB_{it} + \beta_3 GDP_{it} + \beta_4 INF\_GDPDEF_{it} + \beta_5 M\_CAPITAL_{it} + \beta_6 Exc_{it} + e_{it} \quad (3)$$

$$(\widehat{ROE})_{it} = \alpha_0 + \beta_1 SL_{it} + \beta_2 DB_{it} + \beta_3 GDP_{it} + \beta_4 INF\_GDPDEF_{it} + \beta_5 M\_CAPITAL_{it} + \beta_6 Exc_{it} + e_{it} \quad (4)$$

$$(\widehat{NPL})_{it} = \alpha_0 + \beta_1 GL_{it} + \beta_2 DB_{it} + \beta_3 GDP_{it} + +\beta_4 INF\_GDPDEF_{it} + \beta_5 M\_CAPITAL_{it} + \beta_6 Exc_{it} + e_{it} \quad (5)$$

$$(\widehat{CI})_{it} = \alpha_0 + \beta_1 GL_{it} + \beta_2 DB_{it} + \beta_3 GDP_{it} + \beta_4 INF\_GDPDEF_{it} + \beta_5 M\_CAPITAL_{it} + \beta_6 Exc_{it} + e_{it} \quad (6)$$

$$(\widehat{NII})_{it} = \alpha_0 + \beta_1 GL_{it} + \beta_2 DB_{it} + \beta_3 GDP_{it} + \beta_4 INF\_GDPDEF_{it} + \beta_5 M\_CAPITAL_{it} + \beta_6 Exc_{it} + e_{it} \quad (7)$$

$$(\widehat{ROE})_{it} = \alpha_0 + \beta_1 GL_{it} + \beta_2 DB_{it} + \beta_3 GDP_{it} + \beta_4 INF\_GDPDEF_{it} + \beta_5 M\_CAPITAL_{it} + \beta_6 Exc_{it} + e_{it} \quad (8)$$

Where i indexes' countries, t represents years, and $e_{it}$ is the error term, $\alpha$ is the intercept: $\beta_j$ is the estimated regression coefficient of independent variable; j = 1, 2 ,3…6; assuming it follows a normal distribution. Banks' performance taking is measured by the asset quality, profitability, and management efficiency, this study defines dependent variables as the NPL, NII, ROE, and CI.

### 3.8. Support Vector Regression (SVR) Model

The SVR model is formed with 10-fold cross-validation and uses Radial Basis Function (RBF) kernel type. In contrast to the squared loss function in ordinary least-squares regression, $\epsilon$-SVR uses $\epsilon$-insensitive loss function, in which errors smaller than $\epsilon$ will be omitted. It takes the following formula:

$$|Y - f(x)|_{\varepsilon} \equiv max\{0, |Y - f(x)| - \mathcal{E}\} \quad (9)$$

The model mathematics of SVR is:

$$\underset{w,b,\mathcal{E}}{Max} \quad \frac{1}{2} \parallel w \parallel^2 + C \sum_{i=1}^{n} |y_i - f(x)|_{\varepsilon} \qquad (10)$$

The support vectors and values of the solution define the following regression form:

$$f(x) = \sum_{i=1}^{n} \alpha_i K(x, x_i) + b \qquad (11)$$

For a-priory chosen constants $C, \nu$ the dual quadratic optimization problem is as follows:

$$\underset{\alpha,\alpha^*}{max} \quad \sum_{i=1}^{n} (\alpha_i^* - \alpha_i) y_i - \frac{1}{2} \sum_{i,j=1}^{n} (\alpha_i^* - \alpha_i)(\alpha_j^* - \alpha_j)\, K\,(x_i, x_j) \qquad (12)$$

Notably, the prediction performance is evaluated using the following statistical metrics: Root Mean Squared Error (RMSE) and Mean Absolute Error (MAE). To compare the methods used, this study calculated RMSE by using the following formula (Cao and Tay, 2001):

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^{n} (\gamma_i - \ddot{\gamma}_i)^2}$$

# 4. Empirical Results

## 4.1. Model Specification and Descriptive Statistic

Table 2 shows descriptive statistics for the variables used in my regression analysis. As shown, the mean of NPL, CI, NII and ROE of sampled banking sector during 2013-2022 are 3.077656, 60.28953, 40.84157 and 10.23571 respectively. Furthermore, NPLs indicate the share of non-performing loans to total loans, and it median is 2.322714, with a standard deviation of 2.884105 and a range from 0.855252 to 18.03305. While the median return on equity is 10.96347. Further, the standard deviation of CI is 14.43814 and a range from 30.31818 to 97.17094, demonstrating significant variability across banks sectors. The standard deviation of NII and ROE is 13.54230 and 7.679149, respectively. Notably, the mean and median of GL are 0.017332 and 0.002697, respectively, with a minimum value of 0.000000 and a maximum of 0.182780, indicating that some banks sectors have not yet widely used this instrument. While SL ranges from 0.000000 to 0.339583, signifying wide variation in SL across debt markets.

Table 3 displays the correlation analysis results of all independent variables. Based on the correlation analysis, it can be said that the correlation coefficient of SL is positively correlated and significant at a 0.05 level of significance with CI and is negatively correlated at a 0.01 level of significance with ROE. Furthermore, the correlation coefficient of the GL is positively correlated and significant with NII (0.0381<0.05) and is negatively correlated at a 0.05 level of significance with ROE. Specifically, these results suggest a negative association between sustainable lending and return on equity. Additionally, this study assessed the variance inflation factors of all independent variables in the regressions and found VIFs are lower than 2, so the regressions result of independent variables is not adversely influenced by multicollinearity.

Table 2: Descriptive Statistics of Major Variables

| Variable | N | Mean | Median | Minimum | Maximum | Std. Dev. | Skewness | Kurtosis | Jarque-Bera |
|---|---|---|---|---|---|---|---|---|---|
| NPL | 70 | 3.077656 | 2.322714 | 0.855252 | 18.03305 | 2.884105 | 3.727140 | 18.20346 | 836.2417 |
| CI | 70 | 60.28953 | 61.31617 | 30.31818 | 97.17094 | 14.43814 | -0.101738 | 3.346346 | 0.470626 |
| NII | 70 | 40.84157 | 38.29920 | 16.82816 | 72.10167 | 13.54230 | 0.321085 | 2.091584 | 3.609677 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **ROE** | 70 | 10.23571 | 10.96347 | -16.76591 | 26.67098 | 7.679149 | -0.798097 | 4.600370 | 14.90131 |
| **SL** | 70 | 0.031439 | 0.000000 | 0.000000 | 0.339583 | 0.066377 | 2.652619 | 10.45922 | 244.3745 |
| **GL** | 70 | 0.017332 | 0.002697 | 0.000000 | 0.182780 | 0.035101 | 3.084486 | 12.78429 | 390.2166 |
| **DB** | 70 | 87.20296 | 81.59715 | 21.92233 | 182.8681 | 38.62910 | 0.335025 | 2.596485 | 1.784393 |
| **GDP** | 70 | 4.79E+12 | 1.82E+12 | 2.33E+11 | 1.99E+13 | 6.15E+12 | 1.465704 | 3.553373 | 25.95650 |
| **INF_GDPDEF** | 70 | 2.549472 | 1.772440 | -0.223723 | 8.817322 | 2.199943 | 1.186696 | 3.518540 | 17.21380 |
| **M_CAPITAL** | 70 | 75.58457 | 67.95702 | 27.16512 | 193.3464 | 38.38991 | 1.021564 | 3.437527 | 12.73360 |
| **EXC** | 70 | 97.20022 | 97.09690 | 55.58052 | 130.0448 | 14.22830 | -0.089459 | 3.430797 | 0.634661 |

Source: Outputs of data processing using EViews 12.

Table 3: Correlation Matrix

| Variable | SL | GL | DB | GDP | INF_GDP | M_CAPIT | EXC | NPL | CI | NII | ROE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **SL** | 1.000000<br>----- | | | | | | | | | | |
| **GL** | 0.350232<br>0.0030 | 1.000000<br>------ | | | | | | | | | |
| **DB** | 0.159998<br>0.1858 | 0.037952<br>0.7551 | 1.000000<br>------ | | | | | | | | |
| **GDP** | -0.138137<br>0.2541 | -0.178195<br>0.1400 | 0.075490<br>0.5345 | 1.000000<br>------ | | | | | | | |
| **INF_GDP** | -0.275226<br>0.0211 | 0.044992<br>0.7115 | -0.436300<br>0.0002 | -0.234530<br>0.0507 | 1.000000<br>----- | | | | | | |
| **M_CAPIT** | 0.034770<br>0.7751 | -0.057518<br>0.6362 | 0.056755<br>0.6407 | 0.590240<br>0.0000 | -0.339641<br>0.0040 | 1.000000<br>------ | | | | | |
| **EXC** | 0.001220<br>0.9920 | -0.099741<br>0.4114 | 0.531708<br>0.0000 | 0.658349<br>0.0000 | -0.567158<br>0.0000 | 0.416017<br>0.0003 | 1.000000<br>------ | | | | |
| **NPL** | 0.145449<br>0.2296 | -0.010199<br>0.9332 | 0.118185<br>0.3298 | -0.291741<br>0.0143 | -0.205905<br>0.0873 | -0.281867<br>0.0181 | -0.104522<br>0.3892 | 1.000000<br>------ | | | |
| **CI** | 0.262956<br>0.0279 | 0.124917<br>0.3028 | -0.338954<br>0.0041 | -0.323251<br>0.0063 | -0.116052<br>0.3387 | -0.079724<br>0.5118 | -0.399980<br>0.0006 | 0.217409<br>0.0706 | 1.000000<br>------ | | |
| **NII** | 0.162526<br>0.1789 | 0.248498<br>0.0381 | -0.117910<br>0.3310 | -0.228473<br>0.0571 | -0.253256<br>0.0344 | -0.080284<br>0.5088 | -0.215349<br>0.0734 | 0.216890<br>0.0713 | 0.764054<br>0.0000 | 1.000000<br>----- | |
| **ROE** | -0.443243<br>0.0001 | -0.251194<br>0.0359 | -0.124983<br>0.3026 | 0.258018<br>0.0310 | 0.296316<br>0.0127 | 0.132159<br>0.2754 | 0.080765<br>0.5063 | -0.559249<br>0.0000 | -0.711685<br>0.0000 | -0.582782<br>0.0000 | 1.000000<br>----- |

Source: Outputs of data processing using EViews 13. Notes: *p < 0.10; **p < 0.05; ***p < 0.0

## 4.2. Sustainable Lending and banks' performance Empirical Results

Table 4 and 5 present the results of the panel data regression of this study. The data have been analyzed using panel data regression effects for every model. Notably, the white test was employed to test for heteroskedasticity. The empirical results are checked by Lagrange Multiplier and Hausman Tests and Hausman's test suggests that FEM is suitable in the case of NPL and NII models, and therefore

this study presents related models as Table 4. While the REM is superior to FEM in the case of NPL, CI, and NII models, and therefore this study presents random effect models as Table 5.

Table 4: Sustainability linked loans and financial performance in Markets.

| Variables | Model 1<br>NPL | Model 2<br>CI | Model 3<br>NII | Model 4<br>ROE |
|---|---|---|---|---|
| Constant | -5.532517<br>(1.715131) *** | 61.38798<br>(11.76251) *** | 35.82018<br>(17.50059) ** | 27.02373<br>(9.486533) *** |
| SL | -1.309196<br>(1.456624) | 25.70342<br>(9.663638) *** | -17.79216<br>(14.89688) | -26.25882<br>(8.948985) *** |
| DB | 0.105624<br>(0.012305) *** | -0.083926<br>(0.064451) | -0.393324<br>(0.125534) *** | -0.094885<br>(0.046375) ** |
| GDP | -7.20E-13<br>(1.44E-13) *** | -4.98E-13<br>(6.37E-13) | 2.79E-12<br>(1.47E-12) * | 2.50E-14<br>(4.03E-13) |
| INF_GDPD | -0.053750<br>(0.068846) | -0.085242<br>(0.453456) | -0.172132<br>(0.704098) | -0.285233<br>(0.413356) |
| M_CAPIT | -0.006078<br>(0.007492) | -0.049430<br>(0.047077) | 0.050524<br>(0.076505) | 0.029501<br>(0.039096) |
| EXC | 0.035837<br>(0.014641) ** | 0.142259<br>(0.095494) | 0.240566<br>(0.149756) | -0.110148<br>(0.087063) |
| R-squared | 0.962762 | 0.174534 | 0.821867 | 0.196500 |
| Adjusted R-squared | 0.951521 | 0.097146 | 0.769087 | 0.121172 |
| S.E. of regression | 0.635024 | 4.179378 | 6.497524 | 4.205233 |
| F-statistic | 85.64265 | 2.255325 | 15.57151 | 2.608592 |
| Prob (F-statistic) | 0.000000 | 0.048956 | 0.000000 | 0.025214 |
| Best fit model | FEM | REM | FEM | REM |

Notes: Each cell contains the estimated parameters, with Std. Error between brackets, where * denotes p-value of 10%, ** indicates 5% and *** denotes 1%.

The results show the coefficient of the sustainability linked loans (SL) is negative and statistically significant ($P < 0.01$) with ROE, indicating a decrease in the return on equity but is positively and significant with CI, suggesting a decrease the management efficiency. Hence this result does not support the hypothesis, which indicates the banking sector has SL led to decrease in profitability because sustainability practices require a long-run investment that inversely affects financial performance.

Further, table 4 shows the DB is negative and statistically significant with NII and ROE, shows a significant increase in DB may generate decreased profitability. While DB and EXC are positive and significant with NPL, suggesting a decrease in asset quality. Further, GDP is positive effect on NII, indicates the higher GDP, the higher the profitable, and hence supports the second hypothesis, indicates that the performance of the banking sector is driven by macroeconomic factors in markets.

Table 5: Green loans and financial performance in Markets

| Variables | Model 1<br>NPL | Model 2<br>CI | Model 3<br>NII | Model 4<br>ROE |
|---|---|---|---|---|
| Constant | -2.868119<br>(2.067960) | 55.35283<br>(12.01070) *** | 28.28105<br>(15.13682) * | 48.36329<br>(11.27657) *** |
| GL | -11.15995<br>(2.869874) *** | 42.49181<br>(20.44502) ** | 73.73707<br>(29.12941) ** | -42.51089<br>(20.59368) ** |
| DB | 0.073532<br>(0.011117) *** | -0.009712<br>(0.067401) | -0.128931<br>(0.072669) * | -0.253648<br>(0.085710) *** |
| GDP | -4.43E-13<br>(1.18E-13) *** | -8.20E-13<br>(6.46E-13) | -5.60E-13<br>(6.19E-13) | -2.95E-13<br>(9.61E-13) |
| INF_GDPD | -0.000503<br>(0.065292) | -0.324615<br>(0.477934) | -0.775658<br>(0.689911) | -0.146545<br>(0.459347) |
| M_CAPIT | -0.006426<br>(0.006751) | -0.039074<br>(0.047596) | 0.018795<br>(0.061793) | 0.021775<br>(0.047978) |
| EXC | 0.026737<br>(0.013329) ** | 0.147323<br>(0.096923) | 0.278258<br>(0.140779) * | -0.158034<br>(0.094460) |
| R-squared | 0.596072 | 0.139361 | 0.187260 | 0.789341 |
| Adjusted R-squared | 0.557603 | 0.058676 | 0.111065 | 0.726923 |
| S.E. of regression | 0.611092 | 4.273301 | 6.736327 | 4.081497 |
| F-statistic | 15.49476 | 1.727230 | 2.457656 | 12.64614 |
| Prob (F-statistic) | 0.000000 | 0.128991 | 0.033506 | 0.000000 |
| Best fit model | REM | REM | REM | FEM |

Notes: Each cell contains the estimated parameters, with Std. Error between brackets, where *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 5 also reports the result of this study. The results show that green loans (GL) have a positive and significant effect with CI and NII but have a negative and significant effect with NPL and ROE, as H1 is partially accepted. Thus, sustainable lending negatively impacts ROE across all models. This result indicates the banking sector has green loans which led to increase the asset quality and profitability partially. Further, the GDP has a negative and significant effect on NPL, but the DB and EXC have a positive impact on NPL. Finally, DB are negative and statistically significant with ROE and NII is same as table 4. Thus, hypothesis 2 is supported, showing that there is an impact of macroeconomics factors on banks' performance in debt markets.

H1 posits that an increase in sustainable lending leads to improved financial performance. The results support this hypothesis as shown in table 5, indicate that green loans have a significant and positive effect on CI ($\alpha = 42.49181$, $p < 0.05$) and NII ($\alpha = 73.73707$, $p < 0.05$), indicating that green loans lead to better profitability partially. The results reveal that green loans have a significant and negative effect on NPL ($\alpha = -11.15995$, $p < 0.01$) and ROE ($\alpha = -42.51089$, $p < 0.05$), indicating that green loans lead to decrease return on equity and increase asset quality in markets. To ensure the credibility of this study, this study assessed the robustness of the results by using two measures of sustainable lending simultaneously for the explained variables in Models, as shown in Table 6. The results indicate that sustainable lending has a positive effect on financial improvement expect of return

on equity. Also, banks' performance is significantly driven by macroeconomic factors in markets. Therefore, hypothesis 1 is partially supported, but hypothesis 2 is supported.

### 4.3. Robustness Tests

To further validate the reliability of the research results, this study conducted a robustness check by using two measures of sustainable lending simultaneously. The study found that the most appropriate panel data regression model is the REM. The findings using two sustainable lending measures simultaneously are consistent with my previous result, as shown in table 6. The estimated equations of these models are as follows:

$$(\widehat{NPL})_{it} = \alpha_0 + \beta_1 SL_{it} + \beta_2 GL_{it} + \beta_3 DB_{it} + \beta_4 GDP_{it} + \beta_5 INF\_GDPDEF_{it} + \beta_6 M\_CAPITAL_{it} + \beta_7 Exc_{it} + e_{it} \quad (13)$$

$$(\widehat{CI})_{it} = \alpha_0 + \beta_1 SL_{it} + \beta_2 GL_{it} + \beta_3 DB_{it} + \beta_4 GDP_{it} + \beta_5 INF\_GDPDEF_{it} + \beta_6 M\_CAPITAL_{it} + \beta_7 Exc_{it} + e_{it} \quad (14)$$

$$(\widehat{NII})_{it} = \alpha_0 + \beta_1 SL_{it} + \beta_2 GL_{it} + \beta_3 DB_{it} + \beta_4 GDP_{it} + \beta_5 INF\_GDPDEF_{it} + \beta_6 M\_CAPITAL_{it} + \beta_7 Exc_{it} + e_{it} \quad (15)$$

$$(\widehat{ROE})_{it} = \alpha_0 + \beta_1 SL_{it} + \beta_2 GL_{it} + \beta_3 DB_{it} + \beta_4 GDP_{it} + \beta_5 INF\_GDPDEF_{it} + \beta_6 M\_CAPITAL_{it} + \beta_7 Exc_{it} + e_{it} \quad (16)$$

Table (6): Sustainable lending and financial performance in Markets

| Variables | Model 1<br>NPL | Model 2<br>CI | Model 3<br>NII | Model 4<br>ROE |
|---|---|---|---|---|
| Constant | -2.790121<br>(2.103851) | 57.32172<br>(12.26446) *** | 25.47573<br>(15.46555) | 30.15572<br>(9.768397) *** |
| SL | 0.373369<br>(1.391334) | 21.92593<br>(9.814353) ** | -29.14279<br>(14.63177) * | -23.46803<br>(9.090107) ** |
| GL | -11.37339<br>(2.999416) *** | 32.61589<br>(20.63337) | 84.19857<br>(29.61347) *** | -22.82674<br>(18.46949) *** |
| DB | 0.072574<br>(0.011727) *** | -0.039774<br>(0.071706) | -0.106458<br>(0.079037) | -0.121512<br>(0.050965) |
| GDP | -4.37E-13<br>(1.21E-13) *** | -6.48E-13<br>(6.89E-13) | -5.72E-13<br>(6.75E-13) | -4.60E-15<br>(4.40E-13) |
| INF_GDPD | 0.000186<br>(0.065967) | -0.275452<br>(0.466288) | -0.758937<br>(0.686620) | -0.181324<br>(0.427724) |
| M_CAPIT | -0.006550<br>(0.006830) | -0.050600<br>(0.047114) | 0.032294<br>(0.063640) | 0.027182<br>(0.040186) |
| EXC | 0.026580<br>(0.013466) * | 0.150516<br>(0.094603) | 0.283482<br>(0.139568) ** | -0.114243<br>(0.086839) |
| R-squared | 0.596218 | 0.209113 | 0.239124 | 0.225034 |

| | | | | |
|---|---|---|---|---|
| **Adjusted R-squared** | 0.550629 | 0.121237 | 0.154583 | 0.138926 |
| **S.E. of regression** | 0.615981 | 4.058666 | 6.459973 | 4.097793 |
| **F-statistic** | 13.07830 | 2.379628 | 2.828475 | 2.613407 |
| **Prob (F-statistic)** | 0.000000 | 0.031787 | 0.012538 | 0.019599 |
| **Best fit model** | REM | REM | REM | REM |

Notes: Each cell contains the estimated parameters, with Std. Error between brackets, where *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 6 indicate that the findings support two hypotheses in this study, in that sustainability linked loans have a negative effect on ROE ($\alpha$ = -23.46803, $p < 0.05$) and NII ($\alpha$ = -29.14279, $p < 0.10$). Further, the results support that green loans have a significant and positive effect on NII ($\alpha$ = 84.19857, $p < 0.01$), indicating that high green loans lead to improve the profitability partially. The findings support that green loans have a significant and negative effect on NPL ($\alpha$ = -11.37339, $p < 0.01$) and ROE ($\alpha$ = -22.82674, $p < 0.01$), indicating that high green loans lead to decrease return on equity and increase asset quality in markets.

### 4.4. Results of SVMs in regression

The SVR was implemented using the statistica software. The results reveal that the model based on the SVR approach performs better in prediction, compared to the panel data regression model.

Table (7): Estimation of sustainability linked loans in debt markets.

| | **Panel Analysis** | | | | **SVR** | | | |
|---|---|---|---|---|---|---|---|---|
| | NPL | CI | NII | ROE | NPL | CI | NII | ROE |
| **Root MSE** | 0.635024 | 4.179378 | 6.497524 | 4.205233 | 0.493306 | 2.670450 | 2.302326 | 2.049557 |
| **Abs. error mean (MAE)** | --- | --- | --- | --- | 0.457756 | 1.311141 | 0.893765 | 0.835482 |
| **R-squared** | 0.962762 | 0.174534 | 0.821867 | 0.196500 | 0.974354 | 0.967191 | 0.971046 | 0.936982 |

Table (8): Estimation of green loans in debt markets.

| | **Panel Analysis** | | | | **SVR** | | | |
|---|---|---|---|---|---|---|---|---|
| | NPL | CI | NII | ROE | NPL | CI | NII | ROE |
| **Root MSE** | 0.611092 | 4.273301 | 6.736327 | 4.081497 | 0.281014 | 3.187265 | 1.999304 | 2.153918 |
| **Abs. error mean (MAE)** | --- | --- | --- | --- | 0.146009 | 2.696797 | 0.698667 | 0.808097 |
| **R-squared** | 0.596072 | 0.139361 | 0.187260 | 0.789341 | 0.991688 | 0.954472 | 0.978145 | 0.931837 |

Notably, the prediction obtained from panel data regression has an RMSE range between 0.611092 and 6.736327, while the prediction obtained from the SVR has an RMSE range between 0.493306 and 3.187265. The smaller RMSE value means the prediction obtained from the SVR model fits the actual data better than the panel regression model. Therefore, the SVR approach produces a better-fitting model compared to the traditional regression model.

## 5. Conclusion and Recommendation

This study investigated the impact of sustainable lending, represented by sustainability-linked loans and green loans, on the financial performance of banks in emerging and developed markets. The

findings reveal a significant negative effect of sustainability-linked loans on profitability and management efficiency, indicating that these loans may decrease return on equity and increase the cost-to-income ratio. While green loans exhibited a positive effect on profitability partially through non-interest income, they had a negative impact on return on equity and asset quality.

The study also identified macroeconomic factors, such as domestic credit to the private sector, GDP, and exchange rate, as determinants of bank performance. The results indicate that the Support Vector Regression (SVR) model performed better in prediction compared to the panel regression model, highlighting the potential of machine learning techniques in analyzing financial data.

The study contributes to the literature by providing empirical evidence on the impact of sustainable lending on bank performance and employing machine learning techniques. It also has practical implications for policymakers and financial institutions, emphasizing the need for a better understanding of sustainable finance practices and their effects on bank performance. However, the study has limitations, including the potential for unobserved heterogeneity across countries and banks, as well as the exclusion of other potential mediating or moderating factors. Future research could explore the impact of specific sustainable lending instruments or focus on the effect of sustainable finance on banking risks and stability. Additionally, incorporating industry-level analyses or alternative measures of bank performance and sustainable lending could provide further insights.

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