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MASTER´S FINAL WORK
DISSERTATION

HOW DOES PHYSICAL RISK EFFECTS PROFITABILITY OF FINANCIAL COMPANIES?

SAID GASIMOV

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SUPERVISION:
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ABSTRACT

This study investigates the impact of physical risk management on the profitability of financial firms across over 60 countries from 2020 to 2023, utilizing Moody's ESG-Physical Risk Management Score. Analysing a sample of 961 financial institutions, the research reveals a counterintuitive finding: firms with higher physical risk scores, indicative of poorer management of physical risks, are associated with better returns on assets (ROA). This suggests that despite inadequate risk management practices, these firms may leverage financial strategies to offset potential losses. While the effect of physical risk on return on equity (ROE) is less pronounced, larger firm size and higher liquidity emerge as significant positive determinants of equity returns. Non-performing loans (NPL) consistently exhibit a negative relationship with both ROA and ROE, underscoring the critical role of credit risk management. These findings highlight the need for financial firms to prioritize effective physical risk mitigation strategies to enhance profitability and ensure long-term sustainability, despite the observed complexities in the relationship between risk management and financial performance.

KEYWORDS: Financial Industry; Profitability; Climate Change; Physical Risk.

JEL: G20; Q54; D24; F64; O13.

RESUMO

Este estudo investiga o impacto da gestão de riscos físicos na rentabilidade de instituições financeiras em mais de 60 países entre 2020 e 2023, utilizando o Índice de Gestão de Risco Físico da Moody's ESG. Analisando uma amostra de 961 instituições financeiras, a pesquisa revela uma descoberta contraintuitiva: empresas com pontuações mais altas de risco físico, indicativas de uma gestão deficiente dos riscos físicos, estão associadas a melhores retornos sobre ativos (ROA). Isso sugere que, apesar das práticas inadequadas de gestão de riscos, essas empresas podem alavancar estratégias financeiras para compensar possíveis perdas. Embora o efeito do risco físico sobre o retorno sobre o patrimônio líquido (ROE) seja menos pronunciado, o maior tamanho da empresa e a maior liquidez surgem como determinantes positivos significativos dos retornos sobre o patrimônio. Os empréstimos não produtivos (NPL) exibem consistentemente uma relação negativa tanto com o ROA quanto com o ROE, ressaltando o papel crítico da gestão de riscos de crédito. Esses achados destacam a necessidade de as instituições financeiras priorizarem estratégias eficazes de mitigação de riscos físicos para aumentar a rentabilidade e garantir a sustentabilidade a longo prazo, apesar das complexidades observadas na relação entre gestão de riscos e desempenho financeiro.

PALAVRAS-CHAVE: Indústria Financeira; Rentabilidade; Mudanças Climáticas; Risco Físico.

JEL: G20; Q54; D24; F64; O13

GLOSSARY

GDP – Gross Domestic Product.

ROA – Return On Asset

NPL – Non-Performing Loans

ROE– Return on Equity

OLS – Ordinary Least Squares

PR – Physical Risk.

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1. INTRODUCTION

Climate change represents one of the most urgent and complex challenges facing humanity today, with profound implications for the environment, economies, and societies across the globe. Over the past decades, a series of influential studies have significantly advanced our understanding of this phenomenon, highlighting both the risks of inaction and the opportunities for mitigation. Economic losses and the frequency of billion-dollar disasters related to weather and climate events have increased significantly in recent years. These trends underscore the urgency for comprehensive strategies to address climate-related risks and have spurred extensive research into their economic impact.

Early recognition of the economic implications of climate change was highlighted by Rockström and Steffen (2009), who linked climate change directly to global economic systems. Stern warned that without substantial measures to reduce greenhouse gas emissions, the global economy could contract by up to 20%. Conversely, proactive efforts could limit economic losses to around 1% of global GDP annually, profoundly influencing political discourse and policy decisions worldwide. Building upon the recognition of Earth's environmental limits, Rockström and Steffen (2009) introduced the concept of planetary boundaries. This framework identified climate change as one of nine critical thresholds that should not be crossed to prevent irreversible environmental damage. It reshaped perspectives on sustainable development and emphasized the necessity of planetary stewardship. The significant role of methane in driving climate change was brought to prominence by Shindell et al. (2012). This study highlighted methane's short-term but substantial warming potential, advocating for aggressive reductions in methane emissions to achieve quicker climate benefits than focusing on carbon dioxide reductions alone. These findings have influenced global strategies to mitigate greenhouse gases beyond carbon dioxide.

Authoritative reports by the Intergovernmental Panel on Climate Change have significantly shaped our understanding of climate science. The IPCC (2018) offered a detailed analysis of the differences between 1.5°C and 2°C global warming scenarios. It underscored the urgent need for immediate and ambitious climate action to limit temperature rises, influencing global climate negotiations and the goals of the Paris

Agreement. Similarly, the IPCC (2021) provides a comprehensive assessment of the physical science behind climate change, confirming the unequivocal link between human activity and global warming.

In the context of business and finance, climate change introduces both transition and physical risks. Transition risk involves the economic and policy shifts associated with moving towards a low-carbon economy, including regulatory changes, technological advancements, and shifts in market preferences. Physical risk refers to the direct impacts of climate change, such as extreme weather events, rising sea levels, and temperature fluctuations, which can severely disrupt operations and damage assets.

While extensive research has been conducted on transition risks, physical risks have received increasing attention in recent years. Li (2024) examined how firms globally are adapting to physical climate risks, finding that companies facing higher risks are more likely to adopt a broader range of strategies, focusing on both risk management and business-level adaptation. This provides valuable insights into how climate risks influence managerial decision-making and long-term planning. Furthermore Trefalt (2023) highlighted the importance of developing standardized methods to assess climate risks for companies, particularly in light of regulatory requirements like the European Union's Corporate Sustainability Reporting, European Union (2022). The report highlighted the difficulties in accessing climate data and noted that the impact of physical climate risks on business performance and financial metrics is still unclear. Same research suggests that markets do not effectively price physical climate risks, while others indicate that companies exposed to higher physical risks face increased costs of capital.

This work aims to contribute to the literature by examining the link between physical climate risk and the profitability of financial companies. By focusing on a sample of 961 financial firms from over 60 countries between 2020 and 2023, utilizing Moody's ESG-Physical Risk Management Score, and analysing financial performance metrics such as Return on Assets (ROA) and Return on Equity (ROE), this study seeks to provide a deeper understanding of how physical climate risks affect profitability in the financial sector. Specifically, it addresses the research question: How does the management of physical climate risks impact the financial performance of firms in the financial sector?

The remainder of this thesis is organized as follows: Section 2 reviews the existing literature on climate performance in relation to economic and corporate performance, with a focus on how physical risks have been studied. Section 3 outlines the methodology and data used in the analysis. Section 4 presents the results and discusses their implications. Finally, Section 5 offers conclusions, acknowledges limitations, and suggests directions for future research.

2 LITERATURE REVIEW

2.1 Climate

Climate change poses profound risks to financial stability and corporate profitability, particularly in the financial and energy sectors. These risks manifest through physical impacts—such as damage from natural disasters—and transition risks linked to shifts toward low-carbon economies. The literature surrounding this issue has expanded significantly over the years, introducing innovative concepts like the "Green Swan" to understand how these risks may lead to financial crises.

Early recognition of the economic implications of climate change was highlighted by Stern (2007), who linked climate change directly to global economic systems, warning of substantial economic contractions without significant greenhouse gas emission reductions. Rockström and Steffen (2009) introduced the concept of planetary boundaries, identifying climate change as one of nine critical thresholds that should not be crossed to prevent irreversible environmental damage. These foundational works reshaped perspectives on sustainable development and emphasized the necessity of planetary stewardship.

Studies exploring how climate transition risks impact profitability have revealed a significant disconnect between corporate valuations and the underlying risks posed by climate change. For instance, Reboredo and Reboredo (2020) analyzed firm-level Carbon Risk Scores to measure exposure to climate transition risks and found that firms with lower transition risks perform better financially. Notably, the underpricing of climate risks in financial markets began to decrease after international agreements such as COP21, suggesting a growing awareness and incorporation of these risks into financial valuations.

Hámori (2022) supported these conclusions, finding that stocks with lower climate risk exposure offer higher returns. This underpricing of climate transition risks suggests that financial markets have been slow to incorporate these risks into stock valuations, leading to potential vulnerabilities as the shift toward a low-carbon economy accelerates. Zhou et al. (2023) reviewed the financial impacts of natural disasters and long-term climate risks on sectors like insurance, banking, and stock markets, finding that climate-related disasters generally reduce insurer profitability, weaken bank stability, and introduce volatility in stock and bond markets. This is particularly detrimental in low- and middle-income countries, where financial resilience is weaker.

In the energy sector, Joaqui-Barandica and Manotas-Duque (2023) highlighted the complex interplay between climate and macroeconomic factors in determining profitability. Their study found that while macroeconomic variables, such as interest rates, remain primary profitability drivers, climatic conditions have become increasingly important for renewable energy firms. This underscores the growing significance of climate adaptation in financial strategies across sectors.

One of the most critical contributions to this literature is the "Green Swan" concept, introduced by Bolton (2020). The term refers to unpredictable, highly disruptive events that climate change could cause within financial systems, akin to Taleb (2007)"Black Swan" theory. Unlike traditional Black Swan events, the physical and transition risks of climate change are known uncertainties characterized by deep nonlinearity, making them both inevitable and potentially catastrophic for global financial stability. Bolton (2020) emphasize the role of central banks in understanding and addressing these risks, urging them to adopt forward-looking, scenario-based models to capture the radical uncertainty and cascading effects that climate events might trigger.

Sjåfjell (2020) adds to this discussion by exploring the broader financial risks of unsustainability. This research underscores the importance of sustainability in corporate decision-making, particularly for financial firms seeking to remain profitable in the face of systemic environmental risks. Integrating Environmental, Social, and Governance (ESG) factors into long-term financial strategies is becoming increasingly vital as climate impacts intensify.

While the emerging literature on climate-related risks highlights the profound impact of environmental factors on financial stability and profitability, it is essential to consider the traditional internal and external determinants that have long been recognized in the financial sector. The interplay between these traditional factors and climate risks creates a complex landscape that financial institutions must navigate to ensure sustained profitability.

2.2 Traditional Internal Factors Influencing Profitability

Early foundational works by Short (1979) and Bourke (1989) laid the groundwork for investigations into profitability determinants across various financial sectors. These studies focused on identifying key internal factors that affect profitability, such as bank size, capital adequacy, liquidity management, asset quality, and revenue diversification.

In the banking sector, Berger et al. (1987) investigated variables such as bank size and risk exposure in the United States, offering evidence on how internal management decisions impact profitability. Molyneux and Thornton (1992) utilized panel data to investigate profitability drivers, highlighting the importance of factors such as capital adequacy, asset quality, and market structure in determining bank profitability. Margarida and Mendes (2001) focused on banks in Portugal, Spain, France, and Germany, emphasizing aspects like capital adequacy and the loan-to-asset ratio as crucial determinants of profitability.

Boyd and Runkle (1993) examined the size and performance of banking firms, suggesting that expanding bank size can lead to marginal cost savings but may also introduce complexities that offset profitability gains. Miller and Noulas (1997) analyzed portfolio mix and large-bank profitability in the USA, contributing to the understanding of how diversification affects financial performance. Eichengreen and Gibson (2001) proposed a nonlinear relationship between bank size and profitability, where increasing size initially has a positive impact before turning negative due to bureaucratic hurdles.

Berger (1995) investigated the relationship between capital and earnings in banking, revealing a positive relationship between capital ratios and profitability, challenging the conventional wisdom of a negative correlation due to reduced risk and tax shield effects. Athanasoglou et al. (2008) examined bank-specific, industry-specific, and macroeconomic determinants of bank profitability in Greece, providing a comprehensive

view of factors influencing financial performance. Goddard and Molyneux (2004) conducted a cross-sectional and dynamic panel analysis of European banks, supporting the notion that larger banks benefit from cost efficiencies and diversified services.

In the insurance industry, Cummins and Nini (2002) explored the impact of underwriting practices and investment strategies on insurance company profitability. Malik (2011) and Al-Shami (2013) found that capital adequacy enhances financial stability and profitability in the insurance sector, similar to findings in banking.

Liquidity management is imperative to mitigate liquidity risk. Eljelly (2004) highlighted the liquidity–profitability tradeoff in emerging markets, emphasizing the need for efficient liquidity management. Bordeleau and Graham (2010) discussed threshold effects in liquidity management, indicating optimal levels beyond which further increases may diminish profitability. Alshatti (2015) argued for a positive relationship between liquidity and profitability, while Aydemir et al. (2017) found that the impact varies across different contexts.

Asset quality, particularly the prevalence of non-performing loans (NPLs), significantly impacts financial performance. Kosmidou and Pasiouras (2007) revealed a negative correlation between NPLs and profitability. Abata (2014) studied commercial banks in Nigeria, confirming the adverse effect of poor asset quality on profitability. Afriyie et al. (2013) and Buchory (2015) suggest that the relationship can be more complex, depending on specific profitability metrics. Bhattarai (2016) further explores this complexity in the context of Nepalese banks.

Revenue diversification presents both opportunities and challenges. Templeton (1992) found that diversification is associated with lower variance of shareholder returns. Lamont (1997) highlighted potential costs associated with diversification, such as agency problems. Khanna et al. (2001) argued that diversification can reduce risk and lead to greater profitability through economies of scope. DeYoung and Roland (2001) found increased earnings volatility associated with fee-based activities, while Stiroh (2004) linked non-interest income to higher risk and lower risk-adjusted profits.

2.3 Traditional External Factors Influencing Profitability

External variables also play a significant role in shaping financial institutions' profitability. Kosmidou and Pasiouras (2005) demonstrated that higher GDP growth rates

enhance profitability in the Greek commercial banking industry. Kosmidou and Pasiouras (2007) expanded this analysis to the European Union, confirming the positive impact of economic growth. Sufian and Chong (2008) supported this view in the context of the Philippines. However, Sastrosuwito and Suzuki (2012) highlighted that this relationship may vary across different economic contexts, as observed in post-crisis Indonesia.

Inflation's impact on profitability is documented with varied effects. Bourke (1989) found a negative relationship due to banks' inability to accurately predict inflation, leading to squeezed interest margins. Molyneux and Thornton (1992) suggested a positive correlation, as higher inflation allows banks to adjust loan interest rates faster than deposit rates, increasing interest margins. Aburime (2009) also supported the positive correlation in the Nigerian banking context.

2.4 Physical Risk

Despite an extensive body of research on climate change, there remains a notable scarcity of studies focusing specifically on physical climate risks and their effects on financial companies. Physical climate risks—including acute events like floods, storms, and wildfires, as well as chronic shifts such as rising temperatures and sea levels—pose significant threats to businesses and financial markets across various sectors. Multiple studies have highlighted how these risks impact infrastructure, operations, and financial performance. For instance, Pankratz (2023) and Hong and Li (2019) emphasize that critical infrastructures like power generation projects and global supply chains are highly vulnerable to climate-induced disruptions, projecting substantial losses in capacity and efficiency due to factors such as rising water temperatures and extreme weather events. Similarly, Fiedler (2021) and Gu et al. (2023) discuss how industries reliant on water and energy, such as agriculture and manufacturing, face significant vulnerabilities that necessitate integrating physical climate risks into strategic planning.

From a financial perspective, Clarke (2022) and Giglio and Kelly (2021) illustrate how financial markets are beginning to price in physical climate risks. Investors are demanding greater transparency and penalizing companies that fail to disclose or mitigate their exposure, leading to stock price volatility and underperformance. This sentiment is echoed by Krueger (2020) and the CDP (2016) report, which highlight the growing importance of transparent reporting and corporate governance in managing physical risks.

Supporting this, Nicolò Rizzo, (2024) found a positive and significant relationship between physical risk and both the Weighted Average Cost of Capital (WACC) and the cost of equity for non-financial companies in the U.S. market. This suggests that investors view higher physical risk unfavourably, leading to increased capital costs for firms that do not effectively manage these risks. Consequently, investing in robust physical risk mitigation strategies is crucial for companies to optimize capital costs and enhance their market competitiveness. Firms with robust risk management practices are better positioned to attract investment and reduce insurance costs. Kunreuther (2013) and the Global Institute McKinsey (2020) underscore the economic implications of physical risks and the role of risk-sharing mechanisms like insurance and public-private partnerships in mitigating financial impacts. Furthermore, Daniel (2019) and Flammer (2021) advocate for integrating physical climate risks into corporate strategy and governance to enhance resilience, while the Task Force on Climate-related Financial Disclosures TCFD (2017) promotes standardized reporting frameworks and scenario analyses to better access and communicate these risks.

Collectively, these studies converge on the imperative for businesses and investors to proactively address physical climate risks through strategic investments, robust governance, transparent reporting, and adaptation measures to safeguard operations and financial stability in an era of escalating climate challenges. Yet, despite these insights, there is a distinct gap in the literature concerning the specific impact of physical climate risks on financial companies. Given the financial sector's pivotal role in risk management and capital allocation, understanding how physical risks affect financial institutions is essential. This study aims to fill this gap by examining the effects of physical climate risks on the performance and profitability of financial companies, thereby contributing to the broader discourse on climate change and financial stability.

3. SAMPLE AND METHODOLOGY

3.1 Sample Construction

The study aims to investigate the relationship between physical risk management and financial performance in the financial sector, testing the hypothesis that firms with better management of physical risks—measured by the Physical Risk Management Score—have higher profitability, as indicated by Return on Assets (ROA) and Return on Equity

(ROE). It also examines whether this negative effect persists when controlling for firm size, leverage, liquidity, and other financial variables. Building upon existing literature that explores the impact of physical and environmental risks on firm profitability, particularly within the financial sector, this research addresses a notable gap. Prior studies suggest that higher physical risk exposure can lead to increased costs, operational disruptions, and ultimately lower profitability. By analyzing recent data and employing robust econometric models, this study contributes to the understanding of how physical risks influence financial performance in the current global context.

To achieve this, the study examines the relationship between physical risk, financial performance, and firm-specific factors using panel data from 961 firms— banks, diversified investment services, consumer lending, investment management and corporate financial services— across over 60 countries during the period from 2020 to 2023, (detailed composition of subindustry and countries are presented in Appendix I and Appendix II accordingly). This time frame was selected to capture the impact of physical risk factors and various financial variables under both normal economic conditions and disruptions caused by global events. The inclusion of firms from such a diverse range of countries ensures broad geographical coverage and diversity in physical risk exposure, enhancing the robustness and generalizability of the findings. Data on physical risk management scores were sourced from Moody's Orbit database, which provides assessments of how effectively companies manage the physical risks associated with climate change. Financial variables were obtained from the Refinitiv database, offering comprehensive financial information on global companies. The data were meticulously cleaned to ensure consistency across variables, removing duplicate entries and handling missing data. Firms with missing critical data for key variables were excluded from the sample to maintain the integrity and reliability of the analysis.

The sample comprises 961 firms from 2020 to 2023, resulting in 3844 observations in total. Firms were selected based on the availability of key financial and physical risk variables, focusing on the financial sector to capture the unique exposures to risk and regulatory structures inherent in this industry. By integrating these carefully curated datasets and applying robust econometric models, the study provides valuable insights into how physical risks affect the profitability of financial institutions, thereby contributing to both the academic literature and practical understanding in the field.

3.2 Physical Risk Variable

Moody's introduced the ESG-Physical Risk Management Score within its comprehensive framework for evaluating environmental, social, and governance (ESG) risks. This score is designed to measure how effectively companies handle the physical risks posed by climate change, such as flooding, heat stress, hurricanes, rising sea levels, water scarcity, and wildfires. Created to meet the growing demand for robust climate risk assessments, the score utilizes historical data and methodologies that date back to 2004, when Moody's first began incorporating climate-related risk factors into their evaluations (Moody's, 2021).

The score ranges from 0 to 100, with higher values indicating superior management of physical climate risks. To maintain a consistent interpretation, the ESG-Physical Risk Management Score was multiplied by negative one, so that higher scores would represent a lower ability to manage physical risks, aligning with the notion that higher scores are negative. In the ongoing work, discussions will refer to this adjusted ESG-Physical Risk Score (Moody's, 2021).

The ESG-Physical Risk Management Score evaluates companies based on three main criteria: leadership, implementation, and results. Leadership examines the company's strategies, governance structures, and target-setting mechanisms for managing physical climate risks, focusing on the commitment and oversight from top management and boards of directors. Implementation assesses the measures and systems the company has put in place to manage these risks, evaluating their effectiveness and comprehensiveness. This includes adaptation strategies, investment in resilient infrastructure, and the integration of risk management practices into operational processes. Results review performance trends and how the company handles controversies related to physical risks, using key performance indicators (KPIs) to measure success, such as reductions in greenhouse gas emissions and improvements in energy efficiency.

Moody's employs a robust methodology that combines both quantitative and qualitative assessments, utilizing a wide range of data sources. These include company disclosures, third-party datasets, climate models, and satellite imagery. To tailor the assessments to the specific risks and standards of different industries, Moody's utilizes 40

sector-specific models. These models incorporate industry-specific KPIs and risk factors, allowing for nuanced and accurate evaluations Moody's (2021).

The ESG-Physical Risk Management Score is integrated into broader economic models to assess potential impacts on GDP, productivity, and other macroeconomic variables. This involves adjusting GDP projections to reflect chronic physical risks implied by various climate scenarios, such as those from (IPCC, 2021). Economic impacts are evaluated through several channels, including consumption (affected by the loss of productive land due to sea-level rise), net exports (impacted by changes in tourism due to rising temperatures), and productivity (influenced by heat stress and the spread of vector-borne diseases). By incorporating sovereign climate risk scores into these economic models, dynamic adjustments can be made, providing a comprehensive understanding of climate risks over time.

The score serves as a vital tool for investors, regulators, and policymakers. For investors, it offers critical insights into a company's resilience to physical climate risks, informing investment decisions and portfolio management. Understanding a company's ability to manage these risks helps investors assess long-term value and avoid potential losses associated with climate-related disruptions. Regulators use the score to evaluate systemic risks that physical climate factors pose to financial markets and economies, aiding in the development of regulations and guidelines aimed at enhancing corporate transparency and accountability in managing climate risks. Policymakers leverage the score to inform policy decisions related to climate adaptation and mitigation strategies, infrastructure investment, and environmental regulations.

By focusing on comprehensive assessments, utilizing diverse data sources, and employing sector-specific models, Moody's provides a detailed view of how climate risks can affect financial stability and business performance. Since its introduction as part of Moody's efforts to address ESG and climate-related risks starting around 2004, the ESG-Physical Risk Management Score has offered valuable insights into the financial stability and resilience of companies facing climate change

3.3 Profitability Measures

Return on Assets (ROA) and Return on Equity (ROE) are fundamental metrics widely used to evaluate the financial performance of institutions, particularly banks and other

financial entities. In this study, ROA and ROE were employed as the dependent variables to assess profitability in our methodology. Their suitability in the methodology for analyzing financial institutions lies in their ability to provide clear insights into profitability, operational efficiency, and management effectiveness. ROA measures how efficiently a company utilizes its assets to generate net income, reflecting the management's ability to convert assets into profits. This is especially pertinent for banks, where assets primarily consist of loans and other interest-earning instruments. According to Athanasoglou et al. (2008), ROA is a key indicator of bank profitability, highlighting how well a bank's assets are being employed to produce earnings. Gul (2011) also emphasize that ROA is particularly relevant in the banking sector due to the nature of banking operations, where the efficient deployment of assets is crucial for profitability.

ROE measures the profitability relative to shareholders' equity, indicating how effectively a company is using investors' funds to generate profits. For financial institutions, ROE reflects the return on the capital invested by shareholders, serving as a critical metric from an investor's perspective. Petria et al. (2015) assert that ROE is significant for banks as it demonstrates the efficiency with which a bank utilizes shareholders' funds, influencing investment decisions and perceptions of financial health. Petria et al. (2015) highlight ROE's importance as an indicator of financial performance, noting its impact on attracting investment and assessing management effectiveness. The use of ROA and ROE facilitates comparative performance analysis across banks of different sizes and regions, standardizing profitability measures and allowing for industry benchmarking, Dietrich and Wanzenried (2011). Moreover, these ratios align closely with the operations of financial institutions. Banks' assets and equity structures differ significantly from non-financial firms, making ROA and ROE more appropriate measures of performance in the banking sector Goddard and Molyneux (2004). Regulatory bodies emphasize the importance of these metrics, with capital adequacy and profitability ratios like ROE being central to frameworks such as the Basel Accords, Berger (2013). While there are limitations, such as sensitivity to asset valuation and equity composition, the strengths of ROA and ROE in providing clear, comparable measures of performance make them indispensable tools in financial analysis. Their extensive use in empirical studies underscores their relevance and utility in banking research, justifying their inclusion as key variables in methodologies for studying financial institutions.

3.4 Model Specification

To analyze the relationship between physical risk and firm profitability, several econometric models were specified, controlling for firm-specific characteristics and addressing potential econometric issues.

3.4.1 Profitability Methodology

To examine the relationship between physical risk and profitability while accounting for firm-specific characteristics, country, and year effects, three distinct regression models are employed. These models aim to evaluate the research hypothesis that physical risk impacts firm profitability, following a structured approach similar to that of Gonçalves et al. (2022). The dependent variable, profitability, is measured through either Return on Assets (ROA) or Return on Equity (ROE), which represent two key financial performance indicators.

Model 1 assesses the relationship between physical risk and profitability while incorporating country fixed effects but without year fixed effects. The inclusion of country fixed effects improves the robustness of the results by accounting for unobserved country-specific heterogeneity that might influence profitability. The model is specified as follows:

(1)
$$Profitability_{\{i,t\}} = \beta^0 + \beta^1 PR_{\{i,t\}} + \beta^2 Size_{\{i,t\}} + \beta^3 Lev_{\{i,t\}} + \beta^4 Divers_{w_{\{i,t\}}} + \beta^5 NPL_{Pct_{\{i,t\}}} + \beta^6 Liquidity_{\{i,t\}} + \gamma_i \varepsilon_{\{i,t\}}$$

In this equation, i represents each firm and t represents the corresponding year. The dependent variable, profitability, is either the return on assets (ROA) or the return on equity (ROE) for firm i at time t. The main independent variable, PR, is the physical risk score for firm i at time t, reflecting the firm's ability to manage physical and environmental risks. A higher value for PR indicates worse risk management, facilitating interpretation where a lower score is favorable. The control variables include firm size (Size), leverage (Lev), income diversification (Divers), non-performing loan ratio (NPL), and liquidity (Liquidity). The error term is denoted by $\varepsilon_{\{i,t\}}$.

Extending Model 1, Model 2 incorporates both country and year fixed effects to control for unobserved heterogeneity across countries and time periods. The model is specified as:

(2) $$Profitability_{\{i,t\}} = \beta^0 + \beta^1 PR_{\{i,t\}} + \beta^2 Size_{\{i,t\}} + \beta^3 Lev_{\{i,t\}} + \beta^4 Divers_{w_{\{i,t\}}} + \beta^5 NPL_{Pct_{\{i,t\}}} + \beta^6 Liquidity_{\{i,t\}} + \gamma_i + \delta_t + \varepsilon_{\{i,t\}}$$

In this model, $\boldsymbol{\gamma_i}$ represents country fixed effects, capturing country-specific factors such as economic conditions and regulatory environments that might influence profitability. $\boldsymbol{\delta_t}$ represents year fixed effects, accounting for time-specific factors like global economic trends or financial crises.

Model 3 replaces the main physical risk variable with an alternative measure to assess how deviations from industry norms affect profitability. The variable PR Median is calculated by taking the median value of physical risk within each industry and creating dummy variables that are multiplied by the physical risk score. The model is specified as:

(3) $$Profitability_{\{i,t\}} = \beta^0 + \beta^1 PR_{Median_{\{i,t\}}} + \beta^2 Size_{\{i,t\}} + \beta^3 Lev_{\{i,t\}} + \beta^4 Divers_{w_{\{i,t\}}} + \beta^5 NPL_{Pct_{\{i,t\}}} + \beta^6 Liquidity_{\{i,t\}} + \gamma_i + \delta_t + \varepsilon_{\{i,t\}}$$

Here, physical risk median captures how the firm's physical risk management compares to the industry median, indicating whether it is above or below the industry standard.

The variables used in the models are defined as follows:

Physical Risk Score (PR): This variable measures a firm’s management of physical risk. Data is obtained from Moody’s Analytics portal. The inversion facilitates interpretation, where a lower score reflects better physical risk management.

Physical Risk Median (PR Median): Calculated by taking the median value of physical risk within each company and creating dummy variables that are multiplied by the physical risk score. This variable assesses how a firm’s risk management deviates

from industry norms. A positive value indicates worse risk management compared to the industry median.

Firm Size (Size): Measured as the natural logarithm of total assets. Larger firms may have more resources to manage risks and benefit from economies of scale, potentially affecting profitability.

Leverage (Lev): Calculated as the ratio of total equity to total assets. A lower leverage ratio indicates higher financial risk, as it reflects a greater reliance on debt relative to equity. Increased debt obligations can negatively impact profitability through higher interest expenses and an elevated risk of financial distress.

Income Diversification (Divers): Assessed using the Herfindahl-Hirschman Index based on the proportions of interest income and non-interest income to total income. A lower index value indicates greater diversification, which can stabilize earnings and enhance profitability by reducing dependence on a single income source.

Non-Performing Loan Ratio (NPL): Measured as the ratio of non-performing loans to total loans, expressed as a percentage. A higher ratio suggests poor credit quality and increased risk, potentially reducing profitability due to higher loan loss provisions.

Liquidity (Liquidity): Defined as the ratio of cash and equivalents to total assets. Higher liquidity indicates a firm's ability to meet short-term obligations, which can positively influence profitability by reducing the risk of financial distress.

Country fixed effects $\boldsymbol{\gamma_i}$ control for unobservable country-specific characteristics, such as legal systems, market structures, and economic policies, that may affect firm profitability. Year fixed effects $\boldsymbol{\delta_t}$ control for time-specific factors, including economic cycles, regulatory changes, and global events that could impact all firms in a given year.

All models are estimated using Ordinary Least Squares (OLS) regression with robust standard errors to correct for heteroscedasticity, ensuring reliable statistical inference. The inclusion of fixed effects in Models 2 and 3 helps control for unobservable heterogeneity across countries and over time, enhancing the robustness of the results.

By employing these three models, the study aims to comprehensively analyze the impact of physical risk on firm profitability, considering both firm-specific characteristics and broader economic factors. This methodology ensures that the results account for

potential biases arising from unobserved heterogeneity across countries and over time, providing valuable insights into how physical risk management influences profitability in different operating environments.

4. RESULTS

4.1 Descriptive Statistics

Table 1 presents descriptive statistics for the variables used in the analysis of the three models (ROA, ROE, and leverage). The choice of a single descriptive table for all models is justified by the consistency of the independent variables employed across the models.

TABLE 1 SAMPLE DESCRIPTIVE STATISTICS

	Obs.	Mean	Std.Dev	Median	Q1	Q3
ROA	3844	.0088	.0103	.0081	.0049	.0119
ROE	3844	.0937	.0792	.0934	0.629	.1267
Size	3844	3.278	0.124	3.277	3.171	3.356
Leverage	3844	.096	0.053	.088	.065	.115
Diversification	3844	.406	0.109	.444	.365	.488
Physical Risk	3844	84.51	15.904	90	74	100
NPL	3844	.778	1.491	.285	.049	1.005
Liquidity	3844	3.818	20.161	.024	.001	.28

The table highlights important differences across firms in terms of performance, risk, and financial characteristics. The average ROA is 0.88% with moderate variability, while ROE exhibits a higher mean of 9.37% and a greater degree of variability. This difference

is typical for banks, where ROA is usually significantly lower than ROE due to the leverage effect. Banks rely heavily on debt financing, which amplifies returns on equity compared to returns on total assets. Leverage, calculated as the ratio of equity to assets, has a mean of 9.6%, further indicating reliance on debt and a higher level of financial risk.

The average physical risk is 84.51, indicating varied approaches to managing physical risk across firms, and the median risk deviates significantly from the industry norm. Non-performing loans (NPL) have a wide range, with a mean of 0.778, indicating that some firms face significant credit risk, while liquidity, which shows the most substantial variability, highlights differences in firms' capacity to meet short-term obligations.

Table 1 suggests that companies in the sample exhibit notable differences in their risk management, financial structures, and performance measures, providing a foundation for comparative analysis in the subsequent models.

4.2 Regression Results for Return on Assets (ROA)

Table II presents the regression results based on the ordinary least squares (OLS) method, where ROA (Return on Assets) is the dependent variable across all models. Physical risk metrics are key explanatory variables, and control variables such as firm size, leverage, diversification, non-performing loans, and liquidity are included. The models also account for country and year effects when specified.

In Model (1), the results show that physical risk score, which indicates a company's ability to manage physical and environmental risks (where a higher score reflects worse risk management), shows a marginally significant positive relationship with ROA. This counterintuitive result suggests that firms with worse physical risk management may slightly outperform in terms of profitability, though this effect is relatively weak. The leverage is significantly and positively associated with ROA, suggesting that firms with higher leverage tend to achieve better returns, possibly due to the tax benefits of debt financing. Non-performing loans (NPL) have a negative and significant relationship with ROA, indicating that firms with higher credit risk experience reduced profitability. Liquidity is positively and significantly associated with ROA, implying that firms with

higher liquidity are better positioned to generate profits. Income diversification, however, does not show a significant impact on profitability in this model.

TABLE 2 RETURN ON ASSET MODELS RESULT

Variables	(1)	(2)	(3)
Physical Risk	0.0042*	0.0045**	
	(0.0021)	(0.0021)	
Physical Risk Median			0.0009
			(0.0006)
Size	0.0557**	0.0444	0.0352
	(0.025)	(0.027)	(0.026)
Liquidity	0.0107***	0.0107***	0.0108***
	(0.0035)	(0.0035)	(0.0036)
Leverage	5.9245**	5.8346**	5.8691**
	(2.4719)	(2.4753)	(2.4795)
NPL	-0.3327***	-0.3263***	-0.3295***
	(0.093)	(0.097)	(0.097)
Diversification	-0.5296	-0.4839	-0.4856
	(0.4770)	(0.4826)	(0.4821)
Intercept	-0.259	-0.1017	0.4967
	(0.9600)	(1.0938)	(1.0587)
Years	No	Yes	Yes
Industry	Yes	Yes	Yes
Observations	3844	3844	3844
Adj R^2	0.363	0.370	0.368
F-stat	22.5	24.3	23.9

*** *p<.01,* ** *p<.05,* * *p<.1,* respectively (1), (2) and (3) – Pooled OLS.
Robust standard errors are in parentheses.
All variables are defined in Appendix III

Model (2) introduces both country and year fixed effects, and the relationship between physical risk and ROA becomes more pronounced and significant. Firms with worse physical risk management still show a positive association with profitability, suggesting that once we control for country and time-specific factors, these firms may be capitalizing on other strategies or benefits that mitigate the negative effects of poor risk management. Leverage, NPL, and liquidity remain significant determinants of profitability, reinforcing the importance of financial structure and asset quality. Income diversification continues

to have a non-significant effect on profitability, suggesting it may not play a major role in driving ROA.

In Model (3), the physical risk score is replaced by a measure comparing a firm's risk management to the industry median. The results indicate that being worse than the industry median in managing physical risks does not significantly affect profitability. This implies that, within this sample, firms with worse risk management may not necessarily suffer in terms of ROA compared to their industry peers. Leverage, NPL, and liquidity maintain their significance, while income diversification remains an insignificant factor in this model as well.

In conclusion, the findings suggest that worse physical risk management, as measured by a higher physical risk score, may not be as detrimental to profitability (ROA) as expected, especially after controlling for country and time effects. Instead, financial factors like leverage, liquidity, and asset quality play a more critical role in influencing firm profitability. The lack of significance for income diversification implies that it may not be a decisive factor in enhancing ROA in this sample.

4.3 Regression Results for Return on Equity (ROE)

Table III presents the regression results based on the ordinary least squares (OLS) method, with ROE (Return on Equity) as the dependent variable across all models. Physical risk metrics are included as key explanatory variables, with firm-specific control variables such as size, leverage, diversification, non-performing loans, and liquidity. Additionally, country and year fixed effects are incorporated where specified.

In Model (1), the physical risk score, which reflects worse risk management with a higher score, shows a marginal and insignificant relationship with ROE. This indicates that poor physical risk management does not have a direct impact on equity returns in this model. Firm size, on the other hand, is significant and positively related to ROE, suggesting that larger firms tend to achieve better equity returns. Leverage is positively associated with ROE, but this relationship is not statistically significant. Non-performing loans (NPL) exhibit a significant negative relationship with ROE, highlighting that firms facing higher credit risk experience reduced returns. Lastly, liquidity is positively and significantly associated with ROE, implying that firms with higher liquidity are better

positioned to enhance equity returns, while income diversification does not show any significant impact on ROE.

TABLE 3 RETURN ON EQUITY MODELS RESULT

Variables	(1)	(2)	(3)
Physical Risk	0.0019	0.0088**	
	(0.0188)	(0.0184)	
Physical Risk Median			-0.0019
			(0.0061)
Size	0.4872**	0.4516**	0.4114**
	(0.025)	(0.027)	(0.026)
Liquidity	0.0553***	0.0568***	0.0571***
	(0.0156)	(0.0156)	(0.0155)
Leverage	7.2573	6.3277	6.5940
	(8.8981)	(8.7852)	(8.8259)
NPL	-2.7864***	-2.6675***	-2.6736***
	(0.6111)	(0.6342)	(0.6322)
Diversification	-4.8417	-4.2798	-4.2958
	(2.7324)	(2.7729)	(2.7811)
Intercept	-0.0844	-2.3271	-0.5123
	(8.1152)	(8.5324)	(7.6388)
Years	No	Yes	Yes
Industry	Yes	Yes	Yes
Observations	3844	3844	3844
Adj R^2	0.351	0.367	0.367
F-stat	4.35	3.87	3.88

*** *p<.01,* ** *p<.05,* * *p<.1,* respectively (1), (2) and (3) – Pooled OLS.
Robust standard errors are in parentheses.
All variables are defined in Appendix III.

In Model (2), country and year fixed effects are introduced, and the significance of some variables changes. Firm size remains positively and significantly associated with ROE. The physical risk score becomes significant in this model, implying that after controlling for country and time-specific factors, poor physical risk management has a detrimental effect on ROE. Leverage continues to have a positive but non-significant association with ROE, while NPL and liquidity retain their significant roles in affecting profitability. Income diversification remains insignificant.

Model (3) introduces an alternative measure of physical risk, where physical risk is compared to the industry median. The results show that being above or below the industry median in terms of physical risk management does not significantly affect ROE. The key financial variables such as firm size, NPL, and liquidity maintain their significant relationships, while leverage and diversification continue to have no significant impact.

In conclusion, the regression results suggest that poor physical risk management, as indicated by a higher physical risk score, negatively affects ROE when controlling for country and time-specific factors. Meanwhile, firm size, liquidity, and credit risk (NPL) are crucial determinants of ROE. The lack of significance for leverage and income diversification across models implies that these factors may not play a central role in determining returns on equity in this dataset.

4.4 Robustness test

The robustness tests conducted for Return on Assets (ROA) and Return on Equity (ROE) primarily focus on the impact of physical risk management on firm profitability. By employing clustered standard errors at the country level, these tests account for intra-country correlations, thereby enhancing the reliability of the findings.

For ROA, the results show a marginally significant positive relationship with the physical risk score (coefficient = 0.0045). This means that as the physical risk score increases—indicating poorer management of environmental risks—firms surprisingly achieve slightly higher returns on their assets. This counterintuitive finding suggests that firms with weaker physical risk management may be compensating for these deficiencies through other financial strategies or operational efficiencies.

In contrast, the robustness analysis for ROE reveals that leverage does not significantly influence equity returns (coefficient = 0.063), indicating a divergence in how physical risk management affects asset versus equity profitability. The negative impact of non-performing loans (NPL) is consistent across both measures, with coefficients of -0.33 for ROA and -0.027 for ROE, highlighting the critical importance of credit risk management.

Overall, the robustness tests confirm that physical risk management plays a pivotal role in influencing profitability, particularly concerning ROA. By demonstrating that effective management of physical risks correlates with better asset returns, the

analysis underscores the need for firms to prioritize physical risk assessment and mitigation strategies to improve financial outcomes.

5.CONSLUSION

This study explored the relationship between physical risk management and profitability in the financial sector, focusing on a sample of 961 financial firms from over 60 countries between 2020 and 2023. Using Moody's ESG-Physical Risk Management Score, we analyzed how firms' management of climate-related physical risks influenced their financial performance, as measured by Return on Assets (ROA) and Return on Equity (ROE).

The results show a counterintuitive finding: firms with higher physical risk scores, which indicate poorer management of physical risks, were associated with better returns on assets (ROA). This suggests that despite worse physical risk management, these firms may be capitalizing on other financial strategies or market opportunities to offset the negative effects of poor risk management. Financial factors such as leverage and liquidity also had significant positive impacts on ROA, indicating that prudent debt management and sufficient liquidity enable firms to exploit investment opportunities and manage financial obligations effectively. Conversely, firms with higher non-performing loan (NPL) ratios experienced reduced profitability, emphasizing the critical role of credit risk management in maintaining profitability.

For ROE, the relationship between physical risk management and profitability was less pronounced. The basic model showed an insignificant or marginal relationship between poor physical risk management and ROE, suggesting that poor risk management does not necessarily harm equity returns. Instead, firm size emerged as a significant positive determinant of ROE, implying that larger firms benefit from economies of scale and stronger market positions, contributing to better equity returns. Liquidity consistently showed a positive and significant relationship with ROE, highlighting its importance in ensuring financial stability and increasing shareholder value. The NPL ratio remained a significant negative factor, reinforcing the importance of managing credit risk to maintain profitability for shareholders.

Income diversification did not significantly impact either ROA or ROE across the models, indicating that diversifying income sources may not directly enhance profitability

within this sample. The robustness tests, employing country-level clustered standard errors, confirmed the consistency of these results. Specifically, they reinforced the finding that worse physical risk management, as indicated by higher physical risk scores, does not appear to detract from ROA, and highlighted the critical role of leverage, liquidity, and asset quality in determining firm profitability.

It is important to consider the temporal dimension of ESG-related investments, including physical risk management. The measure of return in this study is inherently short term, while investments in ESG and physical risk mitigation often involve substantial upfront costs. These costs can reduce performance in the short term but are likely to yield significant benefits over the long term, such as enhanced resilience, reduced future liabilities, and improved market positioning. This perspective highlights the need for firms and investors to adopt a long-term outlook when evaluating the financial implications of ESG initiatives.

By employing Moody's ESG-Physical Risk Management Score, this study provides valuable insights into how firms' physical risk management affects their financial outcomes, contributing to the growing literature on sustainability and financial performance. However, the study's limitations, including the relatively short time frame and the focus on the financial sector, may impact the broader generalizability of the findings. Additionally, possible bias in the data could affect how we interpret cause-and-effect relationships.

Future research could extend the analysis over a longer time horizon, explore non-linear effects, and include additional measures of physical risk to further investigate how varying degrees of risk management effectiveness influence financial performance. Overall, this study highlights the importance of effective financial practices, such as leverage and liquidity management, in driving profitability, while also revealing that poor physical risk management may not always have the expected negative impact on financial performance. This offers significant implications for corporate managers, investors, and policymakers, encouraging a balanced approach to risk management and financial strategy amid growing climate-related challenges.

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APPENDICES

APPENDIX I SAMPLE COMPOSITION BY SUBINDUSTRY

	N	Percentage (%)	Cumulative
Banks	924	96.15	96.15
Consumer Lending	11	1.14	97.29
Corporate Financial Services	6	0.62	97.92
Diversified Investment Services	4	0.42	98.34
Financial & Commodity Market Operator.	1	0.10	98.44
Investment Banking & Brokerage Services	6	0.62	99.06
Investment Management & Fund Operators	9	0.94	100
Total	961	100.00	

APPENDIX II SAMPLE COMPOSITION BY TOP 15 COUNTRIES

	N	Percentage (%)	Cumulative
United States of America	170	18.95	18.95
Japan	62	6.45	25.40
China	59	6.14	31.54
Norway	42	4.37	35.91
Taiwan	34	3.53	39.45
Indonesia	33	3.43	42.88
Canada	29	3.01	45.90
France	29	3.01	48.92
United Kingdom	29	3.01	51.94
Italy	28	2.91	54.85
India	27	2.80	57.66
Switzerland	25	2.60	60.26
Brazil	22	2.29	62.55
Malaysia	21	2.19	64.69
Other	351	35.31	100.00
Total	961	100.00	

APPENDIX III MODELS VARIABLES DEFINITION

Dependent variables		
ROA	Net Income/ Total Assets	Refinitiv
ROE	Net Income/ Equity	Refinitiv
Explanatory variables		
Physical Risk	Physical Risk score obtained from Moody's Orbit	Moody'S Orbit
Physical Risk Median	Physical Risk x Dummy variable median	Author
Control variables		
Size	Obtained from Refinitiv	Refinitiv
Diversification	Herfindahl-Hirschman Index based on income sources.	Author
Liquidity	Cash & Due from Banks	Refinitiv
Leverage	Equity/total assets	Author
NPL	Non-Performing Loans/ Total Loans	Author
Industry	Industry dummy variable	
Year	Year dummy variable	

DISCLAIMER

This master thesis/internship report/project was developed with strict adherence to the academic integrity policies and guidelines set forth by ISEG, Universidade de Lisboa. The work presented herein is the result of my own research, analysis, and writing, unless otherwise cited. In the interest of transparency, I provide the following disclosure regarding the use of artificial intelligence (AI) tools in the creation of this thesis:

I would like to disclose that I utilized artificial intelligence (AI) tools throughout the development of this thesis. These tools were instrumental in brainstorming ideas, allowing me to explore a wider range of concepts and perspectives effectively. Additionally, I employed AI to summarize certain academic papers, which facilitated a more efficient analysis by presenting key information in a clear manner. While the analytical components of this thesis were conducted independently, the initial summarization helped streamline my research process. Furthermore, I leveraged generative AI to assist in correcting typographical and grammatical errors, ensuring a polished final product. The technology also enhanced my vocabulary, providing suggestions that enriched my writing style and clarity.

Nonetheless, I have ensured that the use of AI tools did not compromise the originality and integrity of my work. All sources of information appropriately cited in accordance with academic standards. The ethical use of AI in research and writing has been a guiding principle throughout the preparation of this thesis.

I understand the importance of maintaining academic integrity and take full responsibility for the content and originality of this work.

Said Gasimov– 15/10/2024