How do Financial Leverage and CO2 Emissions affect the Performance of Venture Capital-Backed Firms?

Sarah Mérian

Dissertation written under the supervision of Professor Fátima Shuwaikh

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Abstract

This research examines the complex interplay between financial leverage, CO2 emissions and the performance, of venture capital-backed companies, investigating their influence on financial metrics and stock market valuations over 3 consecutive one-year-lagged periods.

Focusing on venture capital-backed entities, the study examines the relationship between high financial leverage and lower financial performance indicators such as ROE, ROA and Tobin's Q. Simultaneously, it explores the repercussions of lower CO2 emissions on the financial performance of these companies, with the aim of discovering positive correlations between CO2 emissions and financial indicators.

The methodology uses panel data analysis integrating datasets from Thomson VentureXpert, Compustat via WRDS and Refinitiv Eikon databases. The dataset includes 326 US venture-backed companies from 2002 to 2022, encompassing financial performance, CO2 emissions, and control variables for a comprehensive assessment.

The study findings indicate that higher financial leverage negatively affects ROA and ROE initially, with Tobin's Q showing limited impact. In contrast, lower CO2 emissions consistently correlate with higher ROE, ROA, and Tobin's Q across all periods, although the effect on ROE varies over time.

This study highlights the complex relationships that shape financial dynamics among venture capital-backed companies.

Keywords: Venture Capital, Financial Leverage, CO2 emissions, Financial Performance, Lagged Values

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Author: Sarah Mérian

Abstrato

Esta investigação examina a complexa interação entre a alavancagem financeira, as emissões de CO2 e o desempenho de empresas apoiadas por capital de risco, investigando a sua influência nas métricas financeiras e nas avaliações do mercado de ações durante 3 períodos consecutivos com um ano de defasagem.

Centrando-se em entidades apoiadas por capital de risco, o estudo examina a relação entre elevada alavancagem financeira e indicadores de desempenho financeiro mais baixos, como ROE, ROA e Q de Tobin. Simultaneamente, explora as repercussões de menores emissões de CO2 no desempenho financeiro destas empresas, com o objectivo de descobrir correlações positivas entre as emissões de CO2 e os indicadores financeiros.

A metodologia utiliza análise de dados em painel integrando conjuntos de dados da Thomson VentureXpert, Compustat via WRDS e bancos de dados Refinitiv Eikon. O conjunto de dados inclui 326 empresas apoiadas por capital de risco dos EUA de 2002 a 2022, abrangendo desempenho financeiro, emissões de CO2 e variáveis de controle para uma avaliação abrangente.

As conclusões do estudo indicam que uma maior alavancagem financeira afeta inicialmente negativamente o ROA e o ROE, com o Q de Tobin mostrando impacto limitado. Em contraste, emissões mais baixas de CO2 correlacionam-se consistentemente com ROE, ROA e Q de Tobin mais elevados em todos os períodos, embora o efeito sobre o ROE varie ao longo do tempo.

Este estudo destaca as relações complexas que moldam a dinâmica financeira entre empresas apoiadas por capital de risco.

Palavras-chave: Capital de Risco, Alavancagem Financeira, emissões de CO2, Desempenho Financeiro, Valores defasados

Título: Como a alavancagem financeira e as emissões de CO2 afetam o desempenho das empresas apoiadas por capital de risco?

Autor: Sarah Mérian

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Glossary

CFP	Corporate Financial Performance
CO2	Carbon Dioxide
CSHO	Common Shares Outstanding
CSR	Corporate Social Responsibility
CVC	Corporate Venture Capital
ESG	Environmental, Social, and Governance
GEM	Growth Enterprises Market
GHG emissions	Greenhouse Gas emissions
GIS	Green Innovation Strategy
IPO	Initial Public Offering
IVC	Independent Venture Capital
LBO	Leveraged Buyout
R&D	Research and Development
ROA	Return On Assets
ROE	Return On Equity
SME	Small and Medium-sized Enterprises
VC	Venture Capital
VIF	Variance Inflation Factor
WRDS	Wharton Research Data Services

1 INTRODUCTION

In the contemporary landscape of finance and business, the evaluation of how financial leverage and CO2 emissions (carbon dioxide emissions) intersect to influence the performance of venture capital-backed enterprises stands as an area of critical examination. Since the implementation of the Kyoto Protocol in February 2005, carbon emissions and global warming have emerged as primary concerns regarding corporate environmental performance (Benkraiem et al. 2022). The interplay between financial leverage, environmental impact, and the operational success of businesses is attracting increasing attention due to its multifaceted implications on firm performance, market attractiveness, and sustainability measures.

Understanding the complex relationship between financial leverage and firm performance has long been a central focus within financial studies (R. Yang, Xia, and Wen 2016). However, within the distinctive framework of venture capital-backed firms, this correlation assumes significance due to the to the distinctive financial structures and growth-oriented strategies characterizing these entities. The investigation into the impact of varying levels of financial leverage on performance metrics like Return On Equity (ROE), Return On Assets (ROA), and Tobin's Q in such firms holds implications for investors, policymakers, and management teams seeking insights into optimal financial strategies and risk management in the venture capital (VC) landscape. The decisions taken by a company's board of directors can impact the financial leverage policy (Kijkasiwat, Hussain, and Mumtaz 2022). The use of financial leverage, while potentially enhancing returns, also amplifies risks, where excessive borrowing might lead to bankruptcy amid economic downturns, contrasting with lower-leveraged firms that may maintain solvency due to their higher liquidity (Tharshiga and Velnamby 2016).

Moreover, the exploration of CO2 emissions' influence on the financial performance of these firms emerges as a pivotal consideration the contemporary global concerns surrounding climate change and environmental sustainability. Stakeholders, investors, and consumers are increasingly inclined towards supporting environmentally responsible businesses. In this context, the disclosure of environmental information, including carbon emission management, helps build a positive image for stakeholders and attracts investor funding (Radhouane et al. 2018). Green strategies implemented by companies have a significant positive effect on company value. It is important for businesses to adopt environmentally friendly practices, not

only for sustainability reasons, but also as a way to improve their market value and overall performance (Rachmawati 2021). Therefore, in this era of increased environmental awareness, it becomes imperative to understand the positive impact of lower CO2 emissions on the financial position and attractiveness of VC-funded companies. Furthermore, this study's relevance extends beyond financial considerations, aligning with the global emphasis on Environmental, Social, and Governance (ESG) criteria for investment decisions, making it a key determinant in building investor perceptions and market valuations.

This research aims to deepen the complex relationships among financial leverage, CO2 emissions, and the performance of VC-backed companies (Benkraiem et. al 2023). Firstly, the study comprehensively analyzes the influence of financial leverage on key financial performance metrics (ROE, ROA, Tobin's Q) over 3 consecutive one-year-lagged periods (t+1; t+2; t+3), within the context of firms receiving VC funding. Examining the impact of varying levels of financial leverage on these indicators will provide insights into the relationship between leverage and performance.

Secondly, the research seeks to examine the adverse consequences of less CO2 emissions on the financial performance of VC-backed enterprises over 3 consecutive one-year-lagged periods (t+1; t+2; t+3). Exploring the potential positive correlations between less CO2 emissions and financial metrics, aims to ascertain whether lower emissions lead to better financial performance indicators (Shuwaikh et al 2023).

Moreover, this study aims to understand the complex interplay between financial strategies, environmental sustainability, and VC financing. By analyzing how financial leverage and CO2 emissions interact within the field of VC-backed firms, the research seeks to identify potential trade-offs between financial decision-making, environmental responsibility, and the allure of VC funding.

The methodology employed in this study follows an approach to explore the relationships between financial performance, environmental impact, and contextual variables within VC-

backed firms. The financial performance is analyzed over 3 consecutive one-year-lagged periods (t+1; t+2; t+3). A comprehensive dataset encompassing companies exclusively funded by VC between 2002 and 2022 was compiled using Thomson VentureXpert, Compustat via WRDS (Wharton Research Data Services), and Refinitiv Eikon databases. The study focuses on three main sets of variables: dependent variables encompassing ROE, ROA, and Tobin's Q, independent variables including financial leverage and CO2 emissions, and control variables accounting for Firm Size, Innovation Capacity, Age at Financing, Capital Intensity and Company Status. Empirical modeling involves panel data analysis, examining the impact of financial leverage and CO2 emissions on financial performance indicators, across 3 one-year-lagged periods, using fixed and random effects while integrating various controls. The models aim to elucidate the potential influences of these variables on the financial performance of VC-backed companies and provide nuanced insights into these intricate relationships.

The first contribution of this study aims to provide a nuanced understanding of how financial leverage influences the financial performance of VC-backed firms (Shuwaikh et al. 2023). Financial leverage is often defined to as the degree to which a company utilizes debt in its capital structure. It involves strategically leveraging borrowed funds to magnify potential returns or risks. Within the context of VC-backed enterprises, characterized by distinctive financial structures and growth-oriented strategies, the role of financial leverage assumes heightened importance. These firms operate within an environment that emphasizes rapid growth, innovation, and scalability. Consequently, the strategic deployment of financial leverage becomes a crucial determinant in steering their growth trajectories. Understanding the interplay between varying levels of financial leverage and key financial performance metrics over 3 consecutive one-year-lagged periods , within these dynamic VC-funded enterprises is a focal point of this investigation. This study seeks to unravel the intricate relationship between financial leverage and the financial health of firms receiving VC funding. It aims to delineate how different levels of leverage within these high-growth enterprises impact their financial stability, profitability, and strategic decision-making processes. By dissecting the influence of financial leverage, the research endeavors to offer comprehensive insights into the complex financial dynamics of VC-backed firms (Shuwaikh et al. 2023). Furthermore, the relevance of this study lies in its contribution to the understanding of optimal financial strategies and risk management within the unique landscape of VC financing. It intends to provide stakeholders, investors, policymakers, and management teams with a comprehensive perspective on the

implications and trade-offs associated with leveraging debt in the context of high-growth, innovation-driven businesses, thereby enhancing their informed decision-making abilities in these specialized environments. The study by (Abubakar 2020) presents results indicating that higher financial leverage correlate with a significant decline in ROE. Research by (Chen 2020) elucidating the negative effects of increased financial leverage on firm performance. These findings are relevant for analysing the impact of financial leverage on company performance. The research from (R. Yang, Xia, and Wen 2016) identify a significant negative correlation between financial leverage and enterprise performance, extending these findings to VC-backed firms, which is useful for financial performance analysis of VC-backed companies.

The second contribution of this research aims to exploring the influence of CO2 on the financial performance of VC-backed firms. Today, environmental performance has gained importance as stakeholders, including investors, customers, and regulatory bodies, increasingly value sustainability measures. For firms funded by VC, the significance of environmental performance, especially in terms of CO2 emissions, has grown considerably. These entities, typically characterized by innovation-driven, high-growth strategies, operate in an environment where societal and investor pressures increasingly emphasize environmental responsibility. As such, the evaluation and management of CO2 emissions have become integral components of these firms' strategic decision-making processes. This study seeks to elucidate the relationship between CO2 emissions and the financial performance of VC-backed firms over 3 consecutive one-year-lagged periods. By delving into how varying levels of CO2 emissions may influence financial metrics within these high-growth enterprises, the research aims to offer insights into the impact of environmental performance on financial outcomes. Additionally, the study aims to underscore the relevance of considering environmental sustainability as a determinant in shaping the market perceptions and valuation of VC-funded companies. (Miah, Hasan, and Usman 2021) explored carbon emissions' effects on firms' financial health across emerging economies. (Houqe et al. 2022) analyzed the connection between carbon emissions, agency costs, and financial performance among US firms. (Benkraiem et al. 2022) investigated how carbon performance influences firm market value and the role of leadership, gender diversity, and innovation capacity in this relationship. These studies will be useful in the analysis of CO2 emissions on the financial performance of VC-backed companies.

This thesis investigates " How do Financial Leverage and CO2 Emissions affect the Performance of Venture Capital-Backed Firms?". The article unfolds through distinct sections starting with a comprehensive theoretical background, addressing the influence of VC on company performance, the role of financial leverage in company performance and the impact of co2 emissions on company performance. Following this, the methodology elucidates the data collection process, variables chosen, and empirical modeling techniques employed. The subsequent segment showcases empirical results and discussions, inclusive of descriptive statistics, the matrix correlations, the relation between financial leverage and financial performance, the relation between CO2 emissions and financial performance and the robustness checks. The article concludes by highlighting limitations, suggesting future research directions, and summarizing implications derived from the empirical analyses.

2 THEORETICAL BACKGROUND

2.1 THE INFLUENCE OF VENTURE CAPITAL ON COMPANY PERFORMANCE

2.1.1 Venture capital

VC represents a contemporary financing mechanism that has garnered substantial significance, particularly among small and medium-sized enterprises (SMEs) deeply entrenched in technological innovation (R. Yang, Xia, and Wen 2016). It encompasses an external investment avenue that holds pivotal importance in the startup ecosystem (Jeong et al. 2020). According to Jeong and al. (2020), VC firms, as part of external startup investors, attract significant scholarly attention owing to their role in nurturing and supporting nascent companies.

Furthermore, VC firms offer more than just financial investment; they provide invaluable intangible assets derived from their extensive experience and vast networks (Jeong et al. 2020). As highlighted by (Husain, Javed, and Aldalaien 2021), the evolution of VC from a small-scale firm funding mechanism to a substantial facet within financiers' portfolios underscores its transformative growth. (Gompers et al. 2016) also accentuate the role of VC as a vital funding source for small-scale enterprises, underscoring its integration into financiers' portfolios.

2.1.2 CVC and IVC

Within the realm of VC, two prominent types govern investment mechanisms: Independent Venture Capital (IVC) and Corporate Venture Capital (CVC) (Shuwaikh and Dias 2023). These distinct types exhibit varied characteristics and strategic orientations. (Kang 2018) underscores the dominant role of IVC within the VC landscape, recognized as an iconic representation of VC. IVC operates through specific governance structures elucidated by (Bertoni et al. 2019), where a management company (general partners) manages various capital pools provided by limited partners. Importantly, limited partners refrain from involvement in investment selection and management, ensuring the autonomy of general partners in the IVC model (Paolo and Shuwaikh 2022).

On the other hand, CVC, as detailed by (Döll et al. 2022), involves established companies acquiring minority stakes in established firms, also known as incumbents, in their ventures.

This investment avenue, emphasized by (Battisti et al. 2022), encompasses established companies investing in startups to acquire fresh knowledge and expedite technological advancements.

The trajectory of VC activities has witnessed substantial growth, as highlighted by (Belderbos, Jacob, and Lokshin 2018), firmly establishing CVC as an integral part of the VC ecosystem. (Röhm 2018) accentuates the central role played by corporate VC, particularly through direct minority investments by established firms into small, high-tech companies.

Moreover, (Kim and Park 2017) shed light on the increasing collaborative alliances between startups and established firms, facilitated by CVC investments (Shuwaikh et. al 2023). This strategic approach involves established companies making minority equity investments in private entrepreneurial firm, offering not only financial capital but also complementary resources to foster innovation within startups.

2.1.3 Performance of venture capital

(R. Yang, Xia, and Wen 2016) empirical study delves into the correlation between VC participation and enterprise performance, revealing a significant positive association between the two. This correlation underscores VC's instrumental role in fostering growth and success within enterprises, elucidating its impact on overall company performance. (Benkraiem et al. 2023) provide further insights by emphasizing the integration of environmental responsibility, innovation, and financial performance within CVC investments, signaling a shift toward aligning financial success with environmental stewardship.

Moreover, (Jeong et al. 2020) study, rooted in signaling theory and information asymmetry, posits a positive link between initial VC investment and a startup's subsequent growth and performance. Their findings highlight the strategic significance of early-stage VC investments in bolstering sustainability and enhancing overall performance. Additionally, the research conducted by (Husain, Javed, and Aldalaien 2021) underscores that companies backed by VC exhibit significantly higher growth rates compared to those without such financial support, showcasing the efficacy of VC investors in driving value creation.

Finally, these findings collectively underscore the multifaceted role of VC in shaping enterprise performance. They emphasize the importance of prudent financial decision-making,

particularly within the VC landscape, for sustained business success and growth. Furthermore, the alignment of financial prosperity with environmental responsibility emerges as a crucial aspect for comprehensive and sustainable business performance in the contemporary business landscape.

2.2 THE ROLE OF FINANCIAL LEVERAGE IN COMPANY PERFORMANCE

Several studies have examined the impact of financing leverage on company performance. These studies span diverse sectors and geographic contexts, providing insight into this complex relationship. These studies collectively highlight the importance of understanding how financial leverage influences performance measures of various companies.

Financial leverage is the amount of debt used in the company's capital structure (Adetunji and Akinyemi 2016). It is defined as a strategic use of debt to fund operations and investments, amplifies the impact of returns or losses for shareholders (Aloshaibat 2021). While debt leverage can provide avenues for growth, it simultaneously poses risks due to increased debt obligations and associated costs (Bui 2020). Leveraging debt in a company's capital structure isn't negative, provided it generates higher revenues than its debt cost and remains manageable. Companies must maintain a debt level that doesn't compromise financial flexibility, as failure to meet obligations poses a significant risk of bankruptcy, making financial leverage a primary source of credit risk.(Mirza, Rahat, and Reddy 2016)

The Modigliani-Miller theorem (M&M) asserts that a company's market worth is precisely calculated based on its future earnings and asset value, regardless of its chosen method for financing growth. The theorem suggests that, given certain conditions, how a company raises funds—be it through borrowing, issuing stocks, or reinvesting profits—has no bearing on its overall value. However, empirical studies often deviate from these ideal scenarios, highlighting the complexity and real-world implications of financial decisions, like in the study of Kenn-Ndubuisi and J.I. (Kenn-Ndubuisi and J.I 2019)

Studies consistently demonstrate that increased financial leverage can increase bankruptcy risks and potentially slow down overall corporate performance over time (Kenn-Ndubuisi and J.I 2019). The payment of interest on debt gradually reduces available profits, potentially impacting long-term financial health.

To evaluate a company's financial performance, metrics like ROA and ROE are widely used (Chen 2020). ROE specifically measures the profitability of shareholders' invested funds, serving as a critical indicator for the effectiveness of financial strategies in generating profits.

The research efforts by various scholars such as (Papadimitri, Pasiouras, and Tasiou 2021), (Abubakar 2020), (Chen 2020), and (R. Yang, Xia, and Wen 2016) offer nuanced insights into the relationship between financial leverage and firm performance across different sectors.

The review of the FinTech sector by Papadimitri and al.'s highlights that high financial leverage has a negative impact on both profitability and risk-adjusted performance, signifying the potential obstacle that excessive debt poses to a firm's overall financial health. (Papadimitri, Pasiouras, and Tasiou 2021)

Abubakar's study focusing on Oil and Gas companies reveals that while short-term and long-term debt ratios do not significantly influence financial performance, a higher total debt equity ratio correlates with a notable decline in ROE. This highlight the sector-specific impact of capital structure decisions on shareholder wealth. (Abubakar 2020)

Chen's comprehensive research on Chinese listed companies highlight the negative effects of increased financial leverage on firm performance, highlighting the role of operating leverage in offsetting negative consequences of debt financing in certain industries like real estate. (Chen 2020)

Empirical research by Yang and al. on China's GEM (Growth Enterprises Market) listed companies identifies a significant negative correlation between financial leverage and enterprise performance, indicating that higher levels of financial leverage are significantly associated with reduced enterprise performance metrics. (R. Yang, Xia, and Wen 2016)

Their study extended these insights to VC-backed firms, unveiling an intensified negative impact of financial leverage on performance within this context. Notably, the introduction of VC magnified the adverse effects of financial leverage, accentuating the detrimental consequences of excessive debt within these firms. This underscores the heightened sensitivity of VC-backed companies to the leverage effect, emphasizing the amplification of negative performance outcomes due to increased reliance on debt financing. (R. Yang, Xia, and Wen 2016)

These collective studies show the crucial role of prudent capital structure decisions in balancing debt for growth while mitigating potential risks. Maintaining an optimal balance between debt and equity financing is crucial for sustainable growth and overall financial health (RAHMAN, SAIMA, and JAHAN 2020).

Hypothesis 1: High financial leverage will negatively impact financial performance among VC-backed firms.

2.3 THE IMPACT OF CO2 EMISSIONS ON COMPANY PERFORMANCE

Some studies examining the effects of carbon emissions on firms' financial health reveal a significant influence on performance metrics. Recent research by (Trinks, Mulder, and Scholtens 2020) investigates how carbon efficiency influences various financial parameters, including short-term operating performance measured by ROA, long-term market valuation gauged by Tobin's Q, as well as systematic and total risk. Their findings provide evidence that higher carbon efficiency correlates positively with improved financial outcomes. This underlines the critical significance of sustainability strategies in augmenting financial performance across diverse temporal and risk-related dimensions.

Moreover, the work of (Bătae, Dragomir, and Feleagă 2021) reinforces this perspective, emphasizing the intrinsic link between an efficient environmental strategy and firm value. They assert that an active approach toward environmental sustainability can significantly enhance a company's value. Furthermore, their findings highlight that concrete environmental actions and transparent disclosure practices positively impact firm value. Additionally, their study also emphasizes the positive relationship between emission reductions and financial performance, further supporting the contention that a proactive approach towards carbon emission reduction can yield favorable financial outcomes.

Similarly, the research by (Miah, Hasan, and Usman 2021) explores the effects of carbon emissions on firms' financial health across emerging economies between 2011 and 2020. Their study reveals a negative impact of carbon emissions on various performance indicators, particularly among non-financial firms. This suggests a higher susceptibility of non-financial entities to the repercussions of carbon emissions compared to financial institutions.

Moreover, (Houqe et al. 2022) analyzed the link between carbon emissions and agency costs on financial performance using US firms' data from 2007 to 2016. Their study revealed that

higher carbon emissions corresponded to lower financial performance, especially when market reactions turned negative. Interestingly, the synergy between high carbon emissions and elevated agency costs exacerbated the negative impact on firm performance. These studies collectively underscore the significant implications of carbon emissions on firms' financial health, emphasizing the multidimensional impact of carbon emissions on firm performance.

The Recent research by (Benkraiem et al. 2022) delves into how carbon performance influences a firm's market value and the role of leadership, gender diversity, and innovation capacity in driving this relationship. Their study, conducted using a panel of the world's most sustainable companies between 2013 and 2019, notably reveals a positive impact of carbon performance on firm market value. It suggests that investors reward firms demonstrating lower levels of carbon emissions, particularly those exhibiting higher gender diversity and innovation capacity. Moreover, the findings underscore that rank-up firms, actively striving to improve sustainability, experienced a more pronounced positive effect of carbon performance on their market valuation. Benkraiem et al.'s study reinforces the growing relevance of sustainable practices and environmental considerations in influencing market perceptions and firm valuation. Their findings align with previous literature, emphasizing the value-enhancing potential of carbon emission reduction strategies.

The study by (Shabbir and Wisdom 2020) focuses on exploring the relationship between corporate social responsibility (CSR), particularly internal environmental investments, and financial performance within Nigerian manufacturing firms. Their findings strongly suggest a positive and significant correlation between firms' internal environmental investments and their financial performance. It is highlighted that environmentally conscious firms demonstrated a notably higher level of profitability in contrast to environmentally non-conscious firms. The study's conclusions emphasize the financial advantage for firms actively investing in environmental initiatives, thereby indicating a positive association between CSR initiatives and financial performance within the Nigerian manufacturing sector.

(Lin et al. 2019) conducted research that aimed to investigate the influence of the Green Innovation Strategy (GIS) on Corporate Financial Performance (CFP). Their empirical findings revealed a positive effect of the GIS on CFP. Additionally, this study highlighted a correlation between firm size and returns on green innovation investments. Notably, smaller-sized firms demonstrated a higher return on investments in green innovation compared to their larger-sized

counterparts. This outcome suggested that smaller firms were better positioned to capitalize on green innovation, potentially due to their flexibility and adaptability.

The collective findings from these diverse studies highlight the multidimensional impact of environmental performance (such as carbon emissions) and environmental investments on firm performance and the pivotal role of sustainability practices in shaping market perceptions and firm valuation. They underscore the need for companies to evaluate both direct and indirect effects of carbon emissions on financial health, further highlighting the potential value creation from implementing sustainable strategies.

Hypothesis 2: Lower CO2 emissions will positively affect financial performance among VC-backed firms.

3 DATA AND METHODOLOGY

3.1 SAMPLE SELECTION

The dataset utilized for this study comprises companies based in the United States that have been exclusively funded through VC. Spanning the period from 2002 to 2022, the data was collected from various sources.

All information regarding to VC-funded enterprises was sourced from the Thomson VentureXpert database. Financial and accounting data were extracted from the Compustat database via WRDS. Simultaneously, data concerning CO2 emissions was acquired from Refinitiv Eikon.

The process of merging the datasets involved using Excel's 'vlookup' function to match the company names between the VC-funded entity records and the financial/accounting data. Afterward, the CO2 emissions data was linked to the dataset using the same 'vlookup' function in Excel.

The resulting dataset is robust, incorporating a total of 326 companies with 1312 observations, effectively integrating information regarding financial performance, VC funding, and CO2 emissions for analysis and evaluation.

3.1.1 Dependent variables

Financial performance evaluation within the context of VC-backed companies involves distinct metrics to assess efficiency, profitability, and market value. Three dependent variables - Return On Equity (*roe*), Return On Assets (*roa*), and Tobin's Q (*tobinq*) - serve as indicators in assessing the financial performance and market valuation of these entities. These variables are analysed over 3 consecutive one-year-lagged periods (t+1; t+2; t+3). Most existing studies in this area have generally relied on Tobin's Q and ROA as fundamental metrics to evaluate a company's performance (Chen 2020). The ROE can reflect the final results of the company's operational activities and the profitability of shareholders' investment funds (R. Yang, Xia, and Wen 2016). These three variables were selected based on their relevance in capturing the multifaceted nature of financial performance within such contexts. The study of (Benkraiem et al. 2023), emphasizes the significance of these three metrics, highlighting ROA and ROE as

short-term indicators, describing immediate returns concerning assets and equity, respectively. Furthermore, Tobin's Q represents both short and long-term financial aspects by capturing the intangible value and future growth prospects of firms (Benkraiem et al. 2023). All financial and accounting data necessary to calculate the dependent variables ROE, ROA, and Tobin's Q were retrieved from the Compustat database on WRDS.

ROE, a fundamental measure of profitability, delineates the firm's capacity to generate profits from shareholders' equity. It furnishes insight into the company's efficiency in leveraging shareholders' investments.

$$ROE = \frac{Net\ income}{common\ shares\ outstanding * price\ close\ annual\ fiscal}$$

ROA, another important metric, represents the firm's ability to generate profits from its total asset base. This ratio, computed as net income divided by total assets, provides a comprehensive view of how effectively the company utilizes its assets to generate earnings.

$$ROA = \frac{Net\ income}{total\ assets}$$

Furthermore, Tobin's Q, a comprehensive metric that measures both short and long-term financial performance, signifies the relationship between a firm's market value and the replacement cost of tangible assets. Unlike ROE and ROA, Tobin's Q reveals the intangible value and growth potential by comparing the market value to the cost of tangible assets. It considers the future growth prospects and innovation potential, offering a holistic view of a company's market positioning and intangible worth.

$$Tobin's\ Q = \frac{total\ assets + (csho * price\ close\ annual\ fiscal) - common\ ordinary\ equity}{total\ assets}$$

Where csho = common shares outstanding

3.1.2 Independent variables

To examine the first hypothesis 1 concerning the impact of financial leverage on the financial performance of VC-backed firms, the chosen independent variable is financial leverage (*leverage*). This variable is computed by the following calculation method: division of the sum of total long-term debt and debt in current liabilities by the stockholder equity. These specific financial data were obtained from 'balance sheet items' within the Compustat database accessible through WRDS. This calculation method, derived from fundamental financial ratios, offers insights into the extent to which the firm relies on debt to finance its operations compared to the equity contributed by shareholders. Utilizing this measure as the independent variable make it possible to assess the potential influence of financial leverage on the financial performance metrics, such as ROE, ROA, and Tobin's Q, within the context of VC-backed companies.

$$financial\ leverage = \frac{total\ long\ term\ debt + debt\ in\ current\ liabilites}{stockholder\ equity\ parent}$$

To address the second hypothesis 2 regarding the impact of CO2 emissions on VC-backed firms' financial performance, the independent variable chosen was CO2 emission (co2_emissions). Inspired by (Benkraiem et al. 2023), CO2 emissions were calculated using a logarithmic transformation relative to total revenue. This involved taking the natural logarithm of the ratio between carbon emissions and total revenue, then multiplying the result by (-1) for consistency with similar studies. These carbon emissions data were sourced from Refinitiv Eikon, enabling a comprehensive evaluation of environmental impact. The total revenue was retrieved from the Compustat database on WRDS. This method, inspired by GHG emissions (Greenhouse Gas emissions) emissions calculations, aims to emphasize emissions intensity (carbon emissions per unit of revenue) and uses logarithmic transformations for variable interpretation. It ensures that lower calculated CO2 emission correspond to higher values for environmental performance, aligning with the interpretation across environmental, innovation, and financial performance variables in empirical models.

$$CO2\ emissions = \ln\left(\frac{CO2\ emissions}{Total\ revenue}\right) * (-1)$$

3.1.3 Control variables

In examining the multifaceted relationship between financial leverage, CO2 emissions, and the performance of VC-backed firms, several control variables were incorporated to account for external factors that could potentially influence the outcomes. These control variables are: the firm size, the innovation capacity, the age at financing, the capital intensity and the status of company. They were selected to provide a comprehensive assessment of the contextual nuances impacting the financial and environmental performance of these entities.

The control variable Firm Size (*firmsize*) is computed by taking the natural logarithm of total assets. This metric serves as an indicator of the firm's scale and magnitude within its industry. The data for total assets required for this calculation were retrieved from the Compustat database available on WRDS. Larger firms often exhibit different operational dynamics and access to resources, potentially influencing their financial and environmental performance.

$$Firm\ size = \ln(total\ assets)$$

The control variable Innovation Capacity (*innocapacity*) is measured as the ratio of Research and Development (R&D) expenditure to total revenue. This metric encapsulates the firm's commitment and investment in innovation, reflecting its capacity for technological advancement and adaptation. The data for R&D expenditure and total revenue necessary for this calculation were retrieved from the Compustat database accessible on WRDS.

$$Innovation\ capacity = \frac{R\&D\ expenditure}{Total\ revenue}$$

The control variable Age at Financing (*age_at_financing*) signifies the age at which firms receive VC funding. This variable's data were obtained from the Thomson VentureXpert database. This variable is important for understanding the temporal aspect of funding and its potential implications on subsequent performance. The age at which firms secure VC investments can impact their growth trajectories, strategic decisions, and adaptability.

The control variable Capital Intensity (*capintensity*) is defined as the ratio of capital expenditure to total assets. This metric offers insights into the capital utilization efficiency and investment strategies deployed by VC-backed companies. It delves into the proportion of company resources allocated to capital expenditure concerning the total asset base. The data used for this calculation were retrieved from the Compustat database accessible on WRDS.

$$Capital\ Intensity = \frac{Capital\ expenditure}{Total\ assets}$$

The control variable, Company Status (*status_company*), encompasses various stages and statuses that VC-backed firms may traverse throughout their lifecycle. The statuses considered include Acquisition, Active, In Registration, LBO (Leveraged Buyout), Pending Acquisition, Private, Public, and Went Public. Each status delineates a distinct phase in the company's evolution. *Acquisition* signifies that the company has been acquired by another entity, while *Active* denotes that the company is currently operational and conducting business activities. *In Registration* indicates that the company is in the process of registering for regulatory approvals or compliance. *LBO* signifies that the company has undergone a buyout financed primarily through borrowed funds. *Pending Acquisition* suggests that the company is awaiting completion of an acquisition process. *Private* indicates that the company's shares are not publicly traded on stock exchanges, while *Public* denotes that the company's shares are publicly traded. Lastly, *Went Public* signifies that the company has recently completed an initial public offering (IPO) and its shares are now publicly traded. These data were obtained from the Thomson VentureXpert database.

3.2 EMPIRICAL MODELING

Equation examines the influence of financial leverage on financial performance metrics over 3 consecutive one-year-lagged periods (t+1; t+2; t+3), including ROE, ROA, and Tobin's Q among VC-backed firms. The equation is modeled as follows:

Equation (1):

$$FINPERF_{it} = \beta_0 + \beta_1(leverage) + \beta_2(firmsize) + \beta_3(innocapacity) + \beta_4\,(age\_at\_financing) + \beta_5\,(capintensity) + \beta_6\,(status\_company) + \alpha_i + u_{it}$$

Here, $FINPERF_{it}$ represents the financial performance measured as ROA, ROE, and Tobin's Q. The independent variable $\beta_1(leverage)$ represents high financial leverage, while the control variables $\beta_2(firmsize)$, $\beta_3(innocapacity)$, $\beta_4\,(age\_at\_financing)$, $\beta_5\,(capintensity)$ and $\beta_6\,(status\_company)$ stand for firm size, innovation capacity, age at financing, capital intensity and status company respectively. The inclusion of individual-specific effects α_i and error terms u_{it} accounts for unobserved heterogeneity and random disturbances.

Equation (2) investigates the potential positive impact of lower CO2 emissions on financial performance indicators (ROE, ROA, Tobin's Q) over 3 consecutive one-year-lagged periods within VC-backed firms:

Equation (2):

$$FINPERF_{it} = \beta_0 + \beta_1(co2\_emissions) + \beta_2(firmsize) + \beta_3(innocapacity) + \beta_4\,(age\_at\_financing) + \beta_5\,(capintensity) + \beta_6\,(status\_company) + \alpha_i + u_{it}$$

Here, the independent variable $\beta_1(co2\_emissions)$ signifies CO2 emissions, while the control variables $\beta_2(firmsize)$, $\beta_3(innocapacity)$, $\beta_4\,(age\_at\_financing)$ $\beta_5\,(capintensity)$ $\beta_6\,(status\_company)$ and the inclusion of random effects and error terms ensure a comprehensive analysis.

These equations use a panel data structure, allowing for variation within the company and between company over multiple years. Incorporating random effects α_i facilitates capturing

individual-specific variations while robustly estimating fixed effects coefficients. The validation of hypotheses 1 and 2 is based on the importance and direction of the financial leverage and CO2 emissions coefficients, respectively, for the three financial performance indicators.

Using these models, this study aims to offer detailed insights into how high financial leverage and low CO2 emissions could impact the financial performance of VC-backed firms over 3 consecutive one-year-lagged periods. The structured empirical approach, including various control variables and employing panel data techniques, seeks to provide a comprehensive understanding of the relationship between these variables and financial performance indicators.

4 EMPIRICAL RESULTS AND DISCUSSION

4.1 DESCRIPTIVE STATISTICS & CORRELATION MATRIX

Table 1: Summary statistics

	Mean	SD	Min	Max	Median	Skewness	Kurtosis
roe t1	-.266	.807	-11.713	2.563	-.082	-8.707	105.832
roa t1	-.306	.472	-7.788	1.006	-.229	-6.342	80.578
tobinq t1	4.055	3.502	0.300	24.01	2.885	2.143	8.449
roe t2	-.297	.929	-11.713	2.563	-.078	-7.843	83.331
roa t2	-.304	.505	-7.788	1.006	-.221	-6.689	83.279
tobinq t2	3.988	3.513	0.300	24.01	2.86	2.26	9.222
roe t3	-.289	.938	-11.358	2.563	-.068	-7.332	72.941
roa t3	-.284	.539	-7.788	1.006	-.198	-7.598	93.608
tobinq t3	3.841	3.196	0.300	19.45	2.86	2.019	7.689
leverage	.682	15.35	-206.320	459.88	.12	17.814	645.732
co2 emissions	-2.76	1.489	-11.574	1.902	-2.653	-1.116	7.006
firmsize	5.994	1.334	1.260	11.77	5.83	.91	5.266
innocapacity	.249	.383	0.000	10.83	.18	17.611	457.786
age at financing	22.828	29.707	-146.000	221	15	.669	10.982
capintensity	.023	.032	0.000	.54	.01	5.041	60.774
status company	7.079	1.488	1.000	8	8	-2.418	8.542

The Table (1) shows that significant variations for ROE are observed across the 3 one-year-lagged periods (t+1; t+2; t+3). At time t+1, the mean ROE value of (-0.266), with a standard deviation of (0.807), suggests considerable variability in firms' ability to generate profits from shareholders' equity. The negative skewness (-8.707) and high kurtosis (105.832) imply a concentration of observations towards lower ROE values, potentially indicating challenges in profitability. This variability persists in subsequent periods, with mean ROE values of (-0.297) at t+2 and (-0.289) at t+3, indicating fluctuations in profitability over time.

Similarly, ROA displays significant variability across the different periods. At time t+1, the mean ROA value of (-0.306), with a standard deviation of (0.472), suggests diverse performance levels in utilizing total assets for generating profits. The negative skewness (-6.342) and high kurtosis (80.578) indicate a concentration of observations towards lower ROA values, potentially signaling inefficiencies in asset utilization. This variability persists in subsequent periods, with mean ROA values of (-0.304) at t+2 and (-0.284) at t+3, indicating fluctuations in asset efficiency over time.

Tobin's Q, a measure of firm valuation, also exhibits variability across the three time periods. At time t+1, the mean Tobin's Q value of (4.055), with a standard deviation of (3.502), highlights a diverse range of valuation ratios among the sampled firms. The positive skewness

(2.143) and kurtosis (8.449) suggest a concentration of observations towards lower Tobin's Q values, potentially indicating challenges in market valuation. This variability continues in subsequent periods, with mean Tobin's Q values of (3.988) at t+2 and (3.841) at t+3, suggesting fluctuations in market valuation over time.

Financial Leverage presents variability, with a mean of (0.682) and a high standard deviation of (15.35), indicating important differences in the extent of debt utilization among firms. The extremely positive skewness (17.814) and kurtosis (645.732) suggest a concentration of observations towards lower levels of leverage, potentially indicating a conservative approach to debt financing among these entities.

CO2 emissions exhibit a mean value of (-2.76) and a standard deviation of (1.489), highlighting variations in environmental impact among these firms. The negative skewness (-1.116) suggests a somewhat symmetric distribution of CO2 emissions values, with a notable proportion of firms exhibiting emissions closer to the average within this dataset.

Firm Size statistics indicate variations in the scale of these enterprises, with a mean of (5.994) and a standard deviation of (1.334). The positive skewness (0.91) and kurtosis (5.266) imply a concentration of observations around the mean, indicating a considerable number of firms with sizes closer to the average within this sample.

Innovation Capacity statistics reveal a diverse range of values, with a mean of (0.249) and a standard deviation of (0.383). The positive skewness (17.611) and high kurtosis (457.786) suggest a concentration of observations towards lower levels of innovation capacity, potentially indicating disparities in innovation efforts among these firms.

Finally, Age at Financing statistics describe variations in the timing of VC funding received by these firms, with a mean of (22.828) and a relatively high standard deviation of (29.707). The positive skewness (0.669) and kurtosis (10.982) suggest a concentration of observations around the mean, indicating a considerable number of firms with age at financing values closer to the average within this dataset.

Table 2: Correlation Matrix

Variables	(roe_t1)	(roa_t1)	(tobinq_t1)	(roe_t2)	(roa_t2)	(tobinq_t2)	(roe_t3)	(roa_t3)	(tobinq_t3)	(leverage)	(co2_emissions)	(firmsize)	(innocapacity)	(age_at_financing)	(capintensity)	(status_company)
roe_t1	1.000															
roa_t1	0.639***	1.000														
	(0.000)															
tobinq_t1	0.205***	0.133***	1.000													
	(0.000)	(0.000)														
roe_t2	0.342***	0.341***	0.172***	1.000												
	(0.000)	(0.000)	(0.000)													
roa_t2	0.373***	0.509***	0.190***	0.668***	1.000											
	(0.000)	(0.000)	(0.000)	(0.000)												
tobinq_t2	0.177***	0.136***	0.661***	0.197***	0.158***	1.000										
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)											
roe_t3	0.115**	0.235***	0.102**	0.405***	0.429***	0.156***	1.000									
	(0.013)	(0.000)	(0.027)	(0.000)	(0.000)	(0.001)										
roa_t3	0.190***	0.434***	0.094**	0.345***	0.470***	0.178***	0.806***	1.000								
	(0.000)	(0.000)	(0.042)	(0.000)	(0.000)	(0.000)	(0.000)									
tobinq_t3	0.133***	0.151***	0.497***	0.169***	0.150***	0.653***	0.182***	0.157***	1.000							
	(0.004)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)								
leverage	-0.020	-0.054*	-0.042	-0.171***	-0.112***	0.025	0.014	0.024	-0.015	1.000						
	(0.537)	(0.090)	(0.183)	(0.000)	(0.003)	(0.506)	(0.762)	(0.599)	(0.739)							
co2_emissions	0.120***	0.338***	0.146***	0.150***	0.331***	0.156***	0.142***	0.327***	0.121**	0.010	1.000					
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.005)	(0.000)	(0.016)	(0.748)						
firmsize	0.151***	0.332***	0.096***	0.123***	0.284***	0.072*	0.183***	0.278***	0.050	0.014	0.355***	1.000				
	(0.000)	(0.000)	(0.003)	(0.001)	(0.000)	(0.057)	(0.000)	(0.000)	(0.284)	(0.609)	(0.000)					
innocapacity	-0.084***	-0.347***	-0.005	-0.050	-0.220***	-0.050	-0.199***	-0.443***	-0.027	-0.014	-0.313***	-0.364***	1.000			
	(0.008)	(0.000)	(0.865)	(0.184)	(0.000)	(0.184)	(0.000)	(0.000)	(0.566)	(0.624)	(0.000)	(0.000)				
age_at_financing	0.026	0.041	0.075**	0.020	0.030	0.077**	0.025	0.060	0.056	0.001	0.063**	0.035	-0.053*	1.000		
	(0.424)	(0.204)	(0.020)	(0.600)	(0.434)	(0.043)	(0.597)	(0.196)	(0.232)	(0.982)	(0.040)	(0.216)	(0.060)			
capintensity	0.042	0.135***	0.105***	0.118***	0.175***	0.082**	0.044	0.119**	0.045	0.004	-0.081***	0.197***	-0.063**	0.133***	1.000	
	(0.184)	(0.000)	(0.001)	(0.002)	(0.000)	(0.029)	(0.337)	(0.010)	(0.326)	(0.884)	(0.007)	(0.000)	(0.022)	(0.000)		
status_company	0.110***	0.059*	0.172***	0.128***	0.076**	0.177***	0.041	0.054	0.177***	-0.017	-0.001	-0.038	0.015	-0.083***	-0.021	1.000
	(0.001)	(0.066)	(0.000)	(0.001)	(0.043)	(0.000)	(0.374)	(0.240)	(0.000)	(0.539)	(0.984)	(0.167)	(0.580)	(0.003)	(0.446)	

**** p<0.01, ** p<0.05, * p<0.1*

In the Correlation Matrix in Table (2), ROE, at time period t+1, shows a moderately positive correlation with ROA (0.639***), and a weak positive correlation with Tobin's Q (0.205***). This suggests a significant but not extremely strong relationship between profitability and asset utilization or market valuation at this time point. Similarly, at t+2, the correlation between ROE and both ROA (0.668***) and Tobin's Q (0.197***) remains positive, indicating a consistent but slightly stronger association compared to t+1. However, at t+3, the correlation between ROE and both ROA (0.806***) and Tobin's Q (0.182***) suggests a slightly stronger relationship between profitability and asset utilization, and slightly weaker between profitability and market valuation relative to the previous time periods.

For ROA, at t+1, it exhibits a weak positive correlation with Tobin's Q (0.133***). At t+2, ROA maintains a slightly stronger correlation with Tobin's Q (0.158***), indicating a slightly stronger association with market valuation compared to t+1. Moreover, at t+3, the correlation between ROA and Tobin's Q is (0.157***), highlighting a slightly weaker relationship with market valuation relative to the previous time periods.

When analyzing the correlation between financial leverage and financial performance metrics, significant patterns emerge across the two time periods. At time period t+1, financial leverage shows a weak negative correlation with ROE (-0.020) and a marginally significant negative correlation with ROA (-0.054*), indicating a modest adverse relationship with profitability and asset utilization. Similarly, at t+2, financial leverage displays a significantly negative correlation with both ROE (-0.171***) and ROA (-0.112***), suggesting a stronger adverse association with profitability and asset utilization compared to t+1. However, it's important to note that financial leverage does not exhibit a statistically significant correlation with Tobin's Q at either time period, indicating a lack of clear relationship between financial leverage and market valuation.

CO2 emissions exhibit significant positive correlations with ROA at all three time periods: t+1 (0.338***), t+2 (0.331***), and t+3 (0.327***), indicating that lower CO2 emissions are associated with better asset utilization over time. Similarly, significant positive correlations are observed between CO2 emissions and Tobin's Q at t+1 (0.146***), t+2 (0.156***), and t+3 (0.121**), suggesting that lower CO2 emissions coincide with higher market valuations relative to tangible assets. Moreover, the relationship between CO2 emissions and ROE is significant across all time periods: t+1 (0.120***), t+2 (0.150***), and t+3 (0.142***), indicating a consistent positive association between lower CO2 emissions and ROE.

Firm size exhibits significant positive correlations with all financial performance metrics, with coefficients. This implies that larger VC-backed firms tend to achieve better financial performance and command higher market valuations.

Innovation capacity demonstrates strong negative correlations with both ROE and ROA. This suggests that higher levels of innovation capacity are associated with lower financial performance, contrary to conventional expectations.

Age at financing exhibits mixed correlations with financial metrics, with a statistically insignificant relationship for most cases. However, there is a significant positive correlation with Tobin's Q at t+1 and t+2, with respectively coefficient of (0.075**) and (0.077**).

4.2 RELATIONSHIP BETWEEN FINANCIAL LEVERAGE AND FINANCIAL PERFORMANCE

Table 3: Regression Hypothesis 1

VARIABLES	(1) roe_t1	(2) roa_t1	(3) tobinq_t1	(4) roe_t2	(5) roa_t2	(6) tobinq_t2	(7) roe_t3	(8) roa_t3	(9) tobinq_t3
leverage	-0.00188	-0.00320**	-0.0171	-0.0315***	-0.0124***	0.00926	-1.52e-05	-0.000534	-0.0130
	(0.00266)	(0.00144)	(0.0114)	(0.00628)	(0.00332)	(0.0242)	(0.00738)	(0.00384)	(0.0253)
firmsize	0.0832***	0.0889***	0.339***	0.0615**	0.0880***	0.230*	0.105***	0.0624***	0.205
	(0.0225)	(0.0122)	(0.0971)	(0.0310)	(0.0164)	(0.119)	(0.0402)	(0.0209)	(0.138)
innocapacity	-0.0773	-0.315***	0.379	-0.0458	-0.165***	-0.148	-0.273***	-0.398***	0.0230
	(0.0694)	(0.0376)	(0.299)	(0.0814)	(0.0430)	(0.313)	(0.0856)	(0.0445)	(0.294)
age_at_financing	0.000868	0.000326	0.00890**	0.000838	0.000254	0.00912**	0.000913	0.000918	0.00809
	(0.000896)	(0.000485)	(0.00386)	(0.00119)	(0.000631)	(0.00459)	(0.00150)	(0.000779)	(0.00514)
capintensity	-0.259	0.752	9.528**	2.371*	1.513**	5.636	-1.059	-0.0180	1.196
	(0.958)	(0.519)	(4.126)	(1.257)	(0.664)	(4.838)	(1.452)	(0.755)	(4.984)
status_company	0.0789***	0.0249**	0.397***	0.153***	0.0544***	0.564***	0.138*	0.104***	0.896***
	(0.0216)	(0.0117)	(0.0931)	(0.0388)	(0.0205)	(0.149)	(0.0768)	(0.0400)	(0.264)
Constant	-1.326***	-0.962***	-1.313	-1.834***	-1.217***	-1.825	-1.864***	-1.351***	-4.324**
	(0.207)	(0.112)	(0.891)	(0.334)	(0.176)	(1.285)	(0.607)	(0.316)	(2.084)
Observations	966	966	966	692	692	692	463	463	463
R-squared	0.037	0.183	0.051	0.074	0.133	0.042	0.062	0.229	0.039

Standard errors in parentheses

The regression analysis in Table (3) seeks to understand the relationship between financial leverage (leverage) and financial metrics (ROE, ROA, Tobin's Q) over three consecutive one-year-lagged periods (t+1; t+2; t+3) among VC-backed firms. All models are estimated with random effects. The significance levels of coefficients are denoted by ***, **, and * representing p-values below 0.01, 0.05, and 0.1, respectively.

The analysis of ROE across the three periods reveals varying relationships with financial leverage among VC-backed firms. In t+1, the coefficient is statistically insignificant (-0.00188), indicating no significant association between financial leverage and ROE. However, in t+2, the coefficient becomes statistically significant (-0.0315***) at the 1% level, suggesting a negative relationship between financial leverage and ROE. This implies that higher financial leverage is associated with lower ROE. In contrast, in t+3, the coefficient for financial leverage in relation to ROE is statistically insignificant (-1.52e-05), indicating no significant association between financial leverage and ROE over time. While the immediate impact of financial leverage on ROE is not evident, the significant negative relationship observed in t+2 suggests that increased reliance on debt financing might negatively impact shareholder value in the short term among VC-backed firms.

Across the three periods, the coefficient for financial leverage exhibits varying degrees of significance and directionality concerning different financial performance metrics. Notably, in t+1, the coefficient associated with financial leverage in relation to ROA stands at (-0.00320**) and is statistically significant at the 5% level, indicating that higher financial leverage is associated with lower ROA. This finding suggests that increased reliance on debt financing might negatively impact asset efficiency among VC-backed firms within the first year.

Similarly, in t+2, the coefficient for financial leverage concerning ROA remains statistically significant (-0.0124***) at the 1% level, reaffirming the negative association between financial leverage and asset efficiency over consecutive years. This indicates that firms with higher leverage might face challenges in generating profits from their total asset base.

In contrast, in t+3, the coefficient for financial leverage in relation to ROA is not statistically significant (-0.000534), suggesting that the observed relationship between financial leverage and asset efficiency weakens or becomes insignificant over time. This change in significance implies a potential diminishing impact of financial leverage on ROA as time progresses.

The coefficient of financial leverage in relation to Tobin's Q varies across three periods. In t+1, it is statistically insignificant (-0.0171), indicating no significant correlation between financial leverage

and market valuations. This lack of significance persists in t+2 (0.00926) and t+3 (-0.0130), suggesting a consistent absence of a substantial relationship between financial leverage and market valuations over time.

The control variables also demonstrate notable influences on financial performance metrics across the three periods.

Across all three time periods, firm size exhibits consistently positive statistically significant coefficients at the 1% level for ROE and ROA, indicating that larger firms tend to generate higher returns. However, the coefficient for firm size in relation to Tobin's Q varies across time periods, indicating that the impact on market valuation may differ.

The coefficient for innovation capacity is statistically significant for ROE in t+3, with a value of (-0.273***), indicating that firms with higher innovation capacity tend to achieve lower returns on equity. However, the relationship with ROA varies in t+1, the coefficient is (-0.315***), suggesting a negative impact, while in t+2, it decreases to (-0.165***). In t+3, it returns to a significant negative value of (-0.398***). These results imply that while innovation may influence profitability, its impact fluctuates over time.

Age at financing demonstrates varying impacts on financial performance metrics across different time periods. While older firms tend to command higher market premiums, as indicated by the coefficient for age at financing in relation to Tobin's Q in t+1 and t+2 of (0.890***) and (0,00912***) respectively, the relationship with ROE and ROA may not always be significant. This suggests that the maturity of firms at the time of financing may influence market perceptions but might not directly affect profitability.

The coefficient for capintensity shows significant positive associations with financial metrics in t+2. Specifically, for ROE, the coefficient is (2.371*), indicating that firms with higher capital intensity tend to achieve higher returns on equity. Similarly, for ROA, the coefficient is (1.513**), suggesting a positive impact on asset efficiency. Additionally, for Tobin's Q in t+1, the coefficient is (9.528**), further highlighting the positive association between capital intensity and market valuations.

In conclusion, the regression analysis provides valuable insights into the interplay between financial leverage and various financial performance metrics among VC-backed firms. The varying significance levels and directionality of the coefficients for financial leverage across different financial performance metrics highlight the nuanced nature of this relationship. While higher financial leverage was found to be significantly associated with lower ROA in the first and second periods, its

impact weakened over time, as evidenced by the insignificance of the coefficient in the third period. Similarly, financial leverage did not exhibit a significant association with Tobin's Q across all three periods, indicating its limited influence on market perceptions and asset valuations among VC-backed firms. Furthermore, the analysis of ROE revealed a significant negative relationship between financial leverage and ROE in the second period, suggesting that increased reliance on debt financing may adversely affect shareholder value in the short term. The control variables demonstrated notable influences on financial performance metrics, emphasizing the importance of factors such as firm size and age at financing in shaping financial outcomes. Overall, while direct impacts on profitability and shareholder value remained inconclusive, the findings underscore the complex interplay between financial leverage, performance metrics, and market perceptions within the context of VC-backed firms.

Moreover, these findings echo the empirical research conducted by (R. Yang, Xia, and Wen 2016), which identifies a significant negative correlation between financial leverage and enterprise performance. Furthermore, the results align with the findings of (Chen 2020) study, reinforcing the significant negative correlation between financial leverage and firm performance among venture capital-backed firms.

4.3 RELATIONSHIP BETWEEN CO2 EMISSIONS AND FINANCIAL PERFORMANCE

Table 4: Regression Hypothesis 2

VARIABLES	(1) roe_t1	(2) roa_t1	(3) tobinq_t1	(4) roe_t2	(5) roa_t2	(6) tobinq_t2	(7) roe_t3	(8) roa_t3	(9) tobinq_t3
co2_emissions	0.0181	0.0480***	0.302***	0.0679***	0.0504***	0.357***	0.0427*	0.0503***	0.232*
	(0.0168)	(0.00963)	(0.0969)	(0.0216)	(0.0105)	(0.113)	(0.0239)	(0.0106)	(0.129)
firmsize	0.0490**	0.0473***	0.0831	0.0339	0.0312**	0.00630	0.0565*	0.0329**	0.0167
	(0.0209)	(0.0120)	(0.121)	(0.0279)	(0.0136)	(0.146)	(0.0311)	(0.0137)	(0.168)
innocapacity	-0.352***	-0.590***	-0.441	0.234	-0.472***	0.0259	0.0159	-0.112	-0.314
	(0.131)	(0.0754)	(0.759)	(0.178)	(0.0864)	(0.933)	(0.186)	(0.0826)	(1.008)
age_at_financing	0.000413	0.000238	0.00914**	0.000408	0.000116	0.0121**	0.000876	0.000773	0.0111*
	(0.000750)	(0.000430)	(0.00433)	(0.000975)	(0.000474)	(0.00512)	(0.00106)	(0.000469)	(0.00573)
capintensity	0.629	0.664	10.46**	2.193**	1.111**	4.245	0.641	1.277***	-1.739
	(0.814)	(0.467)	(4.703)	(1.032)	(0.502)	(5.421)	(1.021)	(0.452)	(5.523)
status_company	0.0747***	0.0267**	0.332**	0.0841**	0.0373*	0.539**	0.103*	0.0594**	0.888***
	(0.0226)	(0.0130)	(0.131)	(0.0404)	(0.0197)	(0.212)	(0.0585)	(0.0259)	(0.316)
Constant	-0.962***	-0.498***	1.860	-0.960**	-0.481***	0.893	-1.219**	-0.718***	-2.168
	(0.232)	(0.133)	(1.338)	(0.374)	(0.182)	(1.965)	(0.504)	(0.223)	(2.723)
Observations	806	806	806	581	581	581	393	393	393
R-squared	0.058	0.244	0.048	0.044	0.213	0.047	0.045	0.194	0.041

Standard errors in parentheses

The regression analysis in Table (4) seeks to understand the relationship between financial metrics (ROE, ROA, Tobin's Q) and environmental performance (CO2 emissions) over three consecutive one-year lagged periods (t+1, t+2, t+3). All models are estimated with random effects. The significance levels of coefficients are denoted by ***, **, and * representing p-values below 0.01, 0.05, and 0.1, respectively.

Firstly, the relationship between CO2 emissions and ROE presents a mixed pattern of significance and directionality across the three periods. In t+1, CO2 emissions show no statistically significant relationship with ROE (0.0181). However, in t+2 and t+3, the coefficients remain positive and are statistically significant (0.0679***) and (0.0427*), respectively. These findings suggest a potential positive association between lower CO2 emissions and higher ROE among VC-backed firms.

Secondly, across all three periods, the coefficient for CO2 emissions demonstrates varying degrees of significance and magnitude concerning different financial performance metrics. Notably, CO2 emissions consistently show a significant positive relationship with ROA over t+1 (0.0480***), t+2 (0.0504***), and t+3 (0.0503***), indicating that a reduction in CO2 emissions is associated with higher ROA. This finding underscores the importance of environmental sustainability in enhancing asset efficiency among VC-backed firms across multiple time periods.

Thirdly, the relationship between CO2 emissions and Tobin's Q reveals significant positive associations over t+1 (0.302***), t+2 (0.357***), and t+3 (0.232*). These results suggest that companies with lower CO2 emissions tend to command higher market valuations relative to their tangible assets over consecutive years. Such consistent positive correlations between CO2 emissions and market valuation underscore the favorable market perceptions towards environmentally conscious firms among VC-backed enterprises.

Fourthly, the analysis of control variables sheds light on their influence on financial performance metrics within the context of venture capital-backed firms.

Firm size demonstrates a consistent positive association with both ROE and ROA. Specifically, in t+1, the coefficient for firm size in relation to ROE is (0.0490**), indicating a moderate impact on profitability. This positive relationship extends to t+3, with a coefficient of (0.0565*), highlighting a slightly stronger association. Similarly, firm size exhibits significant positive coefficients for ROA in t+1 (0.0473***) and t+3 (0.0329**), implying that larger firms tend to achieve higher returns on their assets, underscoring the benefits of scale in the venture capital realm.

Across different time periods, innovation capacity demonstrates a consistent negative association with both ROE and ROA. Specifically, in t+1, the coefficient for innovation capacity in relation to ROE is (-0.352***), indicating a substantial adverse effect on profitability. Similarly, for ROA in t+1 and t+2, the coefficients are (-0.590***) and (-0.472***) respectively, highlighting the detrimental influence of innovation capacity on asset efficiency and profitability in the venture capital landscape.

Age at financing exhibits a consistent positive association with Tobin's Q, indicating higher market valuations for firms with older financing. Specifically, in t+1 and t+2, the coefficients for age at financing in relation to Tobin's Q are (0.00914**) and (0.0121**) respectively, signifying a favorable market perception of firms with longer operational histories. Similarly, in t+3, the coefficient remains positive and statistically significant at (0.0111*), further emphasizing the enduring influence of age at financing on market valuations within the VC-backed ecosystem.

The coefficient of capital intensity reveals its significant impact on market valuation and financial performance among venture capital-backed firms. In t+1, Tobin's Q shows a substantial positive coefficient of (10.46**), indicating that firms with higher capital intensity tend to command higher market valuations relative to their tangible assets. Moreover, in t+2, capital intensity demonstrates positive associations with both ROE and ROA, with coefficients of (2.193**) and (1.111**) respectively, underscoring its role in driving profitability and shareholder returns. Furthermore, in t+3, the positive relationship between capital intensity and ROA persists, with a coefficient of (1.277***), highlighting its sustained influence on asset efficiency over time.

In summary, the findings emphasize the significant impact of environmental considerations, particularly CO2 emissions, on the financial performance and market perceptions of VC-backed enterprises. The consistent positive associations between reduced CO2 emissions and higher asset efficiency, market valuations, and ROE underscore the favorable market sentiment towards environmentally conscious firms. Furthermore, the significant influences of control variables underscore their importance in shaping financial dynamics within the VC landscape over time. These conclusions align with similar research conducted by (Benkraiem et al. 2022), which reveals a positive impact of carbon performance on firm market value, corroborating the findings of this study and underscoring the complex interplay between environmental considerations and financial outcomes within the VC ecosystem. Moreover, In line with the findings of (Shuwaikh, Benkraiem, and Dubocage 2023) study, the results highlight the significant impact of environmental considerations, particularly CO2 emissions, on the financial performance and market perceptions of VC-backed enterprises.

4.4 ROBUSTNESS CHECKS

4.4.1 Sensitivity analysis

A sensitivity analysis will be conducted to ensure the robustness of the findings (Benkraiem et al. 2023). This analysis will aim to assess the stability of the results by examining how variations in model specifications or control variables may affect the outcomes. Specifically, the "rreg" function in Stata will be utilized, allowing for robust regression estimation by minimizing the influence of outliers and heteroscedasticity in the data. By employing this method, it can be determined whether the conclusions regarding the impact of financial leverage and CO2 emissions on the performance of venture capital-backed firms remain consistent across different model specifications, thereby enhancing the reliability and validity of the research outcomes.

Table 5: Sensitivity analysis Hypothesis 1

VARIABLES	(1) roe_t1	(2) roa_t1	(3) tobinq_t1	(4) roe_t2	(5) roa_t2	(6) tobinq_t2	(7) roe_t3	(8) roa_t3	(9) tobinq_t3
leverage	-0.000444	-4.24e-06	-0.000978	9.09e-05	-0.00220	0.0120	-0.00487***	-0.00131	0.00199
	(0.000342)	(0.000687)	(0.00693)	(0.000946)	(0.00158)	(0.0139)	(0.000892)	(0.00176)	(0.0160)
firmsize	0.00980***	0.0389***	0.00170	0.0195***	0.0354***	-0.00261	0.000747	0.0320***	0.00860
	(0.00311)	(0.00625)	(0.0631)	(0.00419)	(0.00829)	(0.0686)	(0.00485)	(0.00958)	(0.0915)
innocapacity	-0.273***	-0.669***	-0.246	-0.0663***	-0.526***	0.00941	-0.304***	-0.422***	0.144
	(0.0192)	(0.0385)	(0.389)	(0.0110)	(0.0515)	(0.180)	(0.0103)	(0.0204)	(0.534)
age_at_financing	5.92e-05	0.000279	-0.000276	0.000161	0.000442	-0.000916	0.000400**	0.000889**	0.000273
	(0.000115)	(0.000232)	(0.00234)	(0.000161)	(0.000298)	(0.00264)	(0.000181)	(0.000357)	(0.00321)
capintensity	0.413***	0.698***	5.310**	0.606***	1.347***	4.595*	0.351**	1.009***	2.204
	(0.123)	(0.248)	(2.502)	(0.170)	(0.315)	(2.782)	(0.175)	(0.346)	(3.130)
status_company	0.0249***	0.0272***	0.318***	0.0431***	0.0514***	0.419***	0.0753***	0.116***	0.572***
	(0.00278)	(0.00559)	(0.0564)	(0.00523)	(0.00969)	(0.0857)	(0.00928)	(0.0183)	(0.167)
Constant	-0.285***	-0.556***	0.743	-0.537***	-0.761***	-0.185	-0.616***	-1.244***	-1.541
	(0.0290)	(0.0583)	(0.588)	(0.0451)	(0.0895)	(0.739)	(0.0733)	(0.145)	(1.394)
Observations	965	965	965	691	691	692	463	463	462
R-squared	0.337	0.414	0.041	0.232	0.324	0.043	0.709	0.592	0.029

Standard errors in parentheses

The Table (5) examines the robustness of the impact of financial leverage on financial performance over three consecutive one-year-lagged periods among VC-backed firms. All models are estimated with random effects. The significance levels of coefficients are denoted by ***, **, and * representing p-values below 0.01, 0.05, and 0.1, respectively.

The sensitivity analysis provides valuable insights into the robustness of the initial regression results. Specifically, when comparing the coefficients of financial leverage between the initial regression and the sensitivity analysis, notable differences emerge. In the initial regression, financial leverage exhibits statistically significant negative effects on ROE and ROA at t+2, with coefficients of (–0.0315***) and (-0.0124***) respectively. However, in the sensitivity analysis, the coefficient for financial leverage on ROE at t+2 becomes much smaller and loses statistical significance (9.09e-05), suggesting a weaker impact on ROE. Similarly, the coefficient for financial leverage on ROA at t+2 also decreases substantially and loses significance (-0.00220), indicating a less pronounced effect on ROA.

Moreover, examining the impact of financial leverage on Tobin's Q, the initial regression shows a non-significant coefficient at t+1 (-0.0171), while the sensitivity analysis reveals a smaller but still non-significant coefficient (-0.000978). This suggests that the effect of financial leverage on Tobin's Q remains negligible regardless of the analysis conducted.

Overall, the sensitivity analysis highlights potential variations in the estimated effects of financial leverage on financial performance metrics compared to the initial regression. These differences underscore the importance of robustness checks in validating the stability of regression results and provide a nuanced understanding of the relationship between financial leverage and the financial performance of venture capital-backed firms.

Table 6: Sensitivity analysis Hypothesis 2

VARIABLES	(1) roe_t1	(2) roa_t1	(3) tobinq_t1	(4) roe_t2	(5) roa_t2	(6) tobinq_t2	(7) roe_t3	(8) roa_t3	(9) tobinq_t3
co2_emissions	0.0157***	0.0438***	0.121**	0.0200***	0.0462***	0.152**	0.0197***	0.0497***	0.133
	(0.00230)	(0.00503)	(0.0601)	(0.00279)	(0.00609)	(0.0696)	(0.00318)	(0.00704)	(0.0875)
firmsize	0.000873	0.0188***	-0.0768	-0.00195	0.0159**	-0.0811	-0.00289	0.00767	-0.0849
	(0.00287)	(0.00627)	(0.0749)	(0.00360)	(0.00787)	(0.0899)	(0.00412)	(0.00913)	(0.113)
innocapacity	-0.220***	-0.512***	0.0126	-0.172***	-0.395***	0.993*	-0.103***	-0.388***	0.448
	(0.0180)	(0.0394)	(0.470)	(0.0230)	(0.0501)	(0.573)	(0.0247)	(0.0548)	(0.681)
age_at_financing	8.70e-05	0.000337	0.000315	0.000182	0.000546**	0.00218	0.000361**	0.000987***	0.00435
	(0.000103)	(0.000225)	(0.00269)	(0.000126)	(0.000275)	(0.00315)	(0.000141)	(0.000312)	(0.00387)
capintensity	0.488***	1.077***	6.025**	0.486***	1.221***	5.204	0.330**	0.885***	0.0133
	(0.112)	(0.244)	(2.916)	(0.133)	(0.291)	(3.329)	(0.136)	(0.300)	(3.733)
status_company	0.0219***	0.0320***	0.349***	0.0368***	0.0508***	0.502***	0.0592***	0.101***	0.665***
	(0.00311)	(0.00678)	(0.0810)	(0.00523)	(0.0114)	(0.130)	(0.00776)	(0.0172)	(0.214)
Constant	-0.165***	-0.367***	1.374*	-0.259***	-0.499***	0.0394	-0.433***	-0.809***	-1.120
	(0.0318)	(0.0694)	(0.830)	(0.0484)	(0.106)	(1.207)	(0.0668)	(0.148)	(1.840)
Observations	806	806	806	581	581	581	393	393	393
R-squared	0.374	0.444	0.035	0.346	0.381	0.041	0.338	0.438	0.031

Standard errors in parentheses

The Table (6) examines the robustness of the impact of CO2 emissions on financial performance over three consecutive one-year-lagged periods among VC-backed firms. All models are estimated with random effects. The significance levels of coefficients are denoted by ***, **, and * representing p-values below 0.01, 0.05, and 0.1, respectively.

In the initial regression, CO2 emissions display a significant positive impact on ROE at t+2, with a coefficient of (0.0679***). However, upon conducting the sensitivity analysis, the coefficient for CO2 emissions on ROE at t+2 increases slightly to (0.0200***), maintaining statistical significance. This suggests a sustained positive effect of CO2 emissions on ROE, indicating that lower CO2 emissions positively influence the return on equity among venture capital-backed firms.

Similar to ROE, the initial regression reveals a significant positive coefficient for CO2 emissions on ROA at t+2 (0.0504***). This positive effect persists in the sensitivity analysis, where the coefficient increases marginally to (0.0462***), maintaining statistical significance. These findings suggest that lower CO2 emissions continue to positively affect the return on assets, contributing to enhanced financial performance among VC-backed firms.

In the initial regression, CO2 emissions exhibit a significant positive coefficient on Tobin's Q at t+1 (0.302***), which remains significant in the sensitivity analysis but with a slightly smaller magnitude (0.121**). However, at t+2, while the coefficient in the initial regression is substantial and significant (0.357***), it decreases in the sensitivity analysis and loses statistical significance (0.152**). This indicates a less pronounced effect of CO2 emissions on Tobin's Q at this time period, suggesting potential variations in the impact of CO2 emissions on market valuation.

The sensitivity analysis provides robustness to the initial regression results, confirming the positive relationship between CO2 emissions and financial performance metrics such as ROE and ROA among venture capital-backed firms. However, variations are observed in the estimated effects on Tobin's Q, particularly at t+2, indicating potential differences in market valuation dynamics. Overall, these findings underscore the importance of considering the impact of CO2 emissions on different aspects of financial performance, providing valuable insights for investors and policymakers aiming to promote sustainability in the venture capital ecosystem.

4.4.2 Robustness: new variable added

In order to fortify the robustness of the analysis and explore the potential impact of an additional dimension on the relationship between financial metrics and independent variables, a test of robustness was conducted. In this test, a supplementary variable, namely "fund_stage," was introduced into the regression model. Fund stage refers to the developmental stage of the VC-backed firms at the time of financing. It encompasses four distinct stages: Seed Stage, Early Stage, Later Stage, and Balanced Stage. *Seed Stage* denotes firms in their initial phase of development, often focused on product development and market validation. *Early Stage* signifies companies in the early phases of growth, typically experiencing rapid expansion and market penetration. *Later Stage* refers to more mature firms with established market positions and revenue streams. *Balanced Stage* indicates companies at a stage of equilibrium between growth and stability, often characterized by strategic scaling and optimization efforts. By incorporating fund_stage as an additional control variable, the analysis aims to capture the nuanced effects of developmental stages on the relationship between financial leverage, CO2 emissions, and firm performance.

Table 7: Robustness variable Hypothesis 1

VARIABLES	(1) roe_t1	(2) roa_t1	(3) tobinq_t1	(4) roe_t2	(5) roa_t2	(6) tobinq_t2	(7) roe_t3	(8) roa_t3	(9) tobinq_t3
leverage	-0.00190	-0.00314**	-0.0175	-0.0317***	-0.0123***	0.00821	-0.000264	-0.000416	-0.0153
	(0.00266)	(0.00144)	(0.0115)	(0.00629)	(0.00332)	(0.0242)	(0.00742)	(0.00386)	(0.0254)
firmsize	0.0830***	0.0893***	0.337***	0.0602*	0.0884***	0.224*	0.103**	0.0630***	0.193
	(0.0225)	(0.0122)	(0.0971)	(0.0310)	(0.0164)	(0.119)	(0.0403)	(0.0210)	(0.138)
innocapacity	-0.0764	-0.317***	0.390	-0.0423	-0.166***	-0.132	-0.271***	-0.399***	0.0390
	(0.0695)	(0.0376)	(0.299)	(0.0815)	(0.0431)	(0.314)	(0.0858)	(0.0446)	(0.294)
age_at_financing	0.000889	0.000279	0.00917**	0.000925	0.000227	0.00951**	0.000973	0.000890	0.00865*
	(0.000898)	(0.000486)	(0.00387)	(0.00120)	(0.000632)	(0.00460)	(0.00151)	(0.000784)	(0.00516)
capintensity	-0.230	0.689	9.886**	2.484**	1.478**	6.136	-0.983	-0.0540	1.900
	(0.961)	(0.520)	(4.137)	(1.262)	(0.667)	(4.855)	(1.465)	(0.762)	(5.022)
status_company	0.0791***	0.0244**	0.400***	0.155***	0.0537***	0.574***	0.141*	0.103**	0.925***
	(0.0216)	(0.0117)	(0.0932)	(0.0388)	(0.0205)	(0.149)	(0.0773)	(0.0402)	(0.265)
fund_stage	0.0136	-0.0305	0.173	0.0482	-0.0152	0.213	0.0248	-0.0118	0.230
	(0.0350)	(0.0189)	(0.151)	(0.0471)	(0.0249)	(0.181)	(0.0599)	(0.0312)	(0.205)
Constant	-1.351***	-0.907***	-1.621*	-1.927***	-1.187***	-2.237*	-1.925***	-1.323***	-4.887**
	(0.216)	(0.117)	(0.930)	(0.346)	(0.183)	(1.331)	(0.625)	(0.325)	(2.143)
Observations	966	966	966	692	692	692	463	463	463
R-squared	0.037	0.185	0.053	0.075	0.133	0.044	0.063	0.230	0.042

Standard errors in parentheses

The Table (5) examines the robustness of the impact of financial leverage on financial performance over three consecutive one-year-lagged periods among VC-backed firms. All models are estimated with random effects. The significance levels of coefficients are denoted by ***, **, and * representing p-values below 0.01, 0.05, and 0.1, respectively.

In the robustness test, the coefficients for ROE demonstrated consistent patterns with the initial regression, although with some slight variations. Specifically, at t+1, the coefficient remained negative and statistically insignificant (-0.00190). However, at t+2, the negative impact of financial leverage on ROE persisted and remained statistically significant (-0.0317***), aligning closely with the findings of the initial regression. Similarly, at t+3, the coefficient maintained a negative trend, although with a slightly more negative value (-0.000264), yet it remained statistically insignificant. These results from the robustness test reinforce the earlier findings of a significant negative association between financial leverage and ROE in the second time period, indicating a notable impact on the financial performance of venture capital-backed firms during that period.

Regarding ROA, the initial regression showed statistically significant negative coefficients for periods t+1 and t+2, indicating a negative impact of financial leverage on asset productivity. These coefficients remained negative and significant in the robustness test, with slightly reduced magnitudes, with (-0.00314**) and (-0.0123***), respectively in t+1 and t+2. This suggests a potential weakening of the relationship between financial leverage and ROA over time, althoughstill negative.

In terms of Tobin's Q, the initial regression yielded mixed results, with coefficients oscillating between positive and negative values across different time periods, although statistically insignificant. Similarly, in the robustness test, Tobin's Q coefficients remained statistically insignificant, indicating that financial leverage did not significantly influence market perceptions of VC-backed firms' performance. However, there were notable variations in coefficient magnitudes, particularly in periods t+2 and t+3, suggesting some sensitivity to the inclusion of the fund stage variable.

In conclusion, while the robustness test confirmed the general trends observed in the initial regression regarding the impact of financial leverage on financial performance metrics, there were minor discrepancies in the coefficients. These differences highlight the importance of considering different additional variables in assessing the relationship between financial leverage and financial performance in VC-backed firms.

Table 8: Robustness variable Hypothesis 2

VARIABLES	(1) roe_t1	(2) roa_t1	(3) tobinq_t1	(4) roe_t2	(5) roa_t2	(6) tobinq_t2	(7) roe_t3	(8) roa_t3	(9) tobinq_t3
co2_emissions	0.0184	0.0473***	0.308***	0.0685***	0.0499***	0.363***	0.0433*	0.0503***	0.239*
	(0.0168)	(0.00963)	(0.0970)	(0.0216)	(0.0105)	(0.113)	(0.0240)	(0.0106)	(0.129)
firmsize	0.0490**	0.0475***	0.0815	0.0336	0.0314**	0.00340	0.0559*	0.0329**	0.00920
	(0.0209)	(0.0120)	(0.121)	(0.0279)	(0.0136)	(0.146)	(0.0311)	(0.0138)	(0.168)
innocapacity	-0.350***	-0.594***	-0.410	0.242	-0.478***	0.111	0.0267	-0.112	-0.184
	(0.131)	(0.0754)	(0.759)	(0.178)	(0.0866)	(0.934)	(0.187)	(0.0830)	(1.011)
age_at_financing	0.000429	0.000196	0.00949**	0.000465	6.92e-05	0.0128**	0.000961	0.000775	0.0121**
	(0.000752)	(0.000431)	(0.00434)	(0.000979)	(0.000476)	(0.00514)	(0.00107)	(0.000473)	(0.00577)
capintensity	0.651	0.607	10.93**	2.254**	1.061**	4.891	0.709	1.278***	-0.910
	(0.817)	(0.468)	(4.714)	(1.036)	(0.504)	(5.438)	(1.028)	(0.455)	(5.548)
status_company	0.0753***	0.0252*	0.345***	0.0870**	0.0349*	0.569***	0.108*	0.0595**	0.944***
	(0.0227)	(0.0130)	(0.131)	(0.0406)	(0.0198)	(0.213)	(0.0590)	(0.0261)	(0.318)
fund_stage	0.0102	-0.0268	0.220	0.0264	-0.0214	0.277	0.0269	0.000643	0.325
	(0.0293)	(0.0168)	(0.169)	(0.0388)	(0.0188)	(0.203)	(0.0428)	(0.0189)	(0.231)
Constant	-0.983***	-0.442***	1.404	-1.027***	-0.427**	0.196	-1.299**	-0.719***	-3.134
	(0.240)	(0.137)	(1.383)	(0.387)	(0.188)	(2.029)	(0.520)	(0.230)	(2.805)
Observations	806	806	806	581	581	581	393	393	393
R-squared	0.058	0.246	0.050	0.045	0.214	0.050	0.046	0.194	0.046

Standard errors in parentheses

The Table (8) examines the robustness of the impact of CO2 emissions on financial performance over three consecutive one-year-lagged periods among VC-backed firms. All models are estimated with random effects. The significance levels of coefficients are denoted by ***, **, and * representing p-values below 0.01, 0.05, and 0.1, respectively.

In the initial regression analysis, the coefficient estimates for CO2 emissions are positive, indicating that lower CO2 emissions correspond to higher ROE, across all three time periods.The robustness test confirms these findings, with the coefficients remaining positive and statistically significant. Indeed, in the robustness analysis, the coefficients for ROE are (0.0184) for t+1, (0.0685***) for t+2 and (0.0433*) for t+3. These results provide robust evidence supporting the hypothesis that lower CO2 emissions positively influence ROE among VC-backed firms.

Similar to ROE, the initial regression analysis indicates a positive relationship between CO2 emissions and ROA. Across all three time periods, the coefficients for CO2 emissions are positive and statistically significant, implying that firms with lower CO2 emissions tend to achieve higher returns on assets. The robustness test further supports these findings, with the coefficients for ROA remaining positive and significant. In the sensitivity analysis, the coefficients for ROA are (0.0473***) for t+1, (0.0499***) for t+2 and (0.0503***) for t+3, reaffirming the positive association between lower CO2 emissions and higher returns on assets among VC-backed firms.

In the initial regression analysis, Tobin's Q exhibits a positive relationship with CO2 emissions, although with varying significance levels across different time periods. The robustness test validates these findings, with Tobin's Q coefficients remaining positive and significant. For instance, in the sensitivity analysis, the coefficients for Tobin's Q are (0.308***) for t+, (0.363***) for t+2 and (0.239*) for t+3. These results underscore the favorable market perceptions towards VC-backed firms with reduced CO2 emissions, highlighting the importance of environmental considerations in shaping market valuations.

Overall, the robustness test results reinforce the initial findings by demonstrating the stability of the relationships between CO2 emissions and financial performance metrics even with the introduction of 'fund_stage' as an additional control variable. While there are some minor variations in coefficient magnitudes and significance levels, the overall pattern remains supportive of the hypothesis that lower CO2 emissions positively affect financial performance among VC-backed firms. In alignment with the study of (Yuniarti, Soewarno, and Isnalita 2022), the results emphasize the positive impact of lower CO2 emissions on financial performance metrics among venture capital-backed firms.

5 LIMITATIONS AND AVENUES FOR FUTURE RESEARCH

This study recognizes several limitations in the interpretation of the results. First, human errors may have occurred during the process of merging data from various databases, potentially leading to inconsistencies or inaccuracies in the final dataset. Despite meticulous efforts to ensure data accuracy, such errors could influence the overall results and should be acknowledged.

Second, the choice of control variables could introduce bias into the results. Although the selected control variables were carefully considered based on established literature and theoretical frameworks, their influence on the results cannot be ignored. Alternative control variables or refinement of selection criteria could allow a more nuanced understanding of the relationship between financial leverage, CO2 emissions and firm performance.

Furthermore, by selecting the period from 2002 to 2022, it becomes possible to examine long-term trends and dynamics. However, it is crucial to point out that a significant portion of the data used to ensure the robustness of the study comes from the period between 2015 and 2022, which may bias the conclusions.

Another limitation concerns the amount of data analyzed, which could be considered insufficient due to the limited availability of comprehensive data sets. Although the study used the most comprehensive data available, a larger and more diverse dataset could improve the generalizability and robustness of the results. Future research efforts should aim to access larger datasets or use different methodologies to corroborate findings and ensure their validity in different contexts.

Several avenues for future research emerge from these limitations. First, integrating advanced data validation techniques and using robust data management protocols can mitigate human errors in data integration processes, thereby improving the accuracy and reliability of analyses. Additionally, exploring alternative control variables and performing sensitivity analyzes could offer more comprehensive insights into the complex relationship between financial leverage, CO2 emissions and firm performance.

Additionally, expanding the dataset by including more diversified companies or from different regions could enrich the analysis, providing a broader understanding of the impact of financial leverage and CO2 emissions on company performance. Further research efforts could also focus on integrating qualitative methodologies to complement quantitative analyses.

6 CONCLUSION AND IMPLICATIONS

The comprehensive analysis conducted in this study sought to investigate the intricate relationships between financial metrics, environmental considerations, and control variables among VC-backed firms. Hypothesis 1 posited that high financial leverage would negatively impact financial performance, while hypothesis 2 proposed that lower CO2 emissions would positively affect financial performance. Through regression analyses and robustness checks, various insightful relationships and nuances emerged, shedding light on the multifaceted nature of these associations within the VC landscape. The analysis of financial performance delved into over 3 consecutive one-year-lagged periods (t+1; t+2; t+3), each offering insights into the dynamics of VC-backed firms' financial performance.

The examination of hypothesis 1 revealed intricate dynamics between financial leverage and financial performance metrics. While the study revealed statistically significant negative associations between financial leverage and ROA in the periods t+1 and t+2, as well as a negative relationship with ROE in t+2, these associations weakened over time. The absence of significant impacts on Tobin's Q across all periods indicated limited influence on market perceptions. The study emphasized the significance of control variables, such as firm size and age at financing, in shaping financial performance metrics, underscoring the nuanced nature of these relationships and the potential influence of external factors. These findings are consistent with the studies conducted by (R. Yang, Xia, and Wen 2016) and (Chen 2020).

The analysis of hypothesis 2 delves into the intricate relationship between environmental considerations, particularly CO2 emissions, and financial performance metrics among VC-backed firms. Across three consecutive one-year lagged periods, financial performance metrics exhibit varying degrees of significance and magnitude concerning CO2 emissions. Notably, a consistent positive association between reduced CO2 emissions and higher ROA is observed over all periods, indicating the importance of environmental sustainability in enhancing asset productivity within the VC landscape. Similarly, the positive correlation between lower CO2 emissions and Tobin's Q underscores the favorable market perceptions towards environmentally conscious firms, persisting across consecutive years. The relationship between CO2 emissions and ROE displays a positive pattern, with varying significance over time. While the robustness test validates these findings by affirming the stability of the relationships between CO2 emissions and financial performance metrics, there is slight variations in coefficient magnitudes. Nonetheless, the overall pattern supports the

hypothesis that lower CO2 emissions positively influence financial performance among VC-backed firms, emphasizing the significance of integrating environmental factors into financial assessments within this context. These results are consistent with the findings of (Benkraiem et al. 2022) and (Shuwaikh, Benkraiem, and Dubocage 2023).

Furthermore, the robustness checks conducted, including sensitivity analysis and the introduction of a new variable, provided deeper insights into the stability and reliability of the findings. These assessments unveiled subtle adjustments and possible fluctuations in certain relationships across different time frames or among specific variables. Control variables also demonstrated multifaceted impacts across both analyses, underscoring the complexity of their influence on financial metrics within the VC-backed landscape.

In conclusion, this study provides a comprehensive analysis of the intricate relationships between financial metrics, environmental considerations, and control variables among VC-backed firms. The investigation into hypotheses 1 and 2 sheds light on the multifaceted nature of these associations. While hypothesis 1 highlights the nuanced impact of financial leverage on various financial performance metrics, hypothesis 2 underscores the significance of environmental sustainability in shaping financial outcomes within the VC landscape. The robustness checks conducted validate the stability of the findings. Overall, the study underscores the complexity and interplay of factors influencing financial performance among VC-backed firms, emphasizing the need for a holistic understanding of these relationships. Future research endeavors could further explore additional variables and datasets to enhance our understanding of the evolving financial dynamics within the VC ecosystem, contributing to informed decision-making and sustainable investment practices in the future.

In addition, the realm of VC-backed enterprises often witnesses the utilization of non-dilutive financing, such as government grant, presenting an alternative to reduce financial leverage. This form of funding, varying in prevalence across countries, occasionally originates as financial assistance from governments. Some countries exhibit a more pronounced inclination towards extending such financial aids to businesses involved in innovative projects and those actively engaged in ecological transition initiatives.

Government grant acts as a strategic tool for companies, especially among those pursuing innovative ventures or embarking on environmentally sustainable actions. Governments, recognizing the importance of fostering innovation and environmental stewardship, offer supportive mechanisms to encourage such endeavors. By availing these non-dilutive financial options and without financial

interests, firms could mitigate their dependence on debt financing, potentially impacting their financial leverage positively.

This nuanced aspect of financial strategy, often intertwined with governmental policies and initiatives promoting innovation and environmental responsibility (Yang et al 2023), deserves consideration when evaluating the complex financial dynamics of VC-backed firms.

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