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**Pham Hieu**

Faculty of Economics, Ho Chi Minh City University of Technology and Education (HCMUTE) (Vietnam), Thu Duc, Vietnam;  
 ORCID: [0000-0003-4068-5190](https://orcid.org/0000-0003-4068-5190)

**Dang Quang Vang**

D.Sc. in Economics, Faculty of Economics, Ho Chi Minh City University of Technology and Education (HCMUTE) (Vietnam), Thu Duc, Vietnam;  
 e-mail: [vangdq@hcmute.edu.vn](mailto:vangdq@hcmute.edu.vn)  
 ORCID: [0000-0002-9468-2318](https://orcid.org/0000-0002-9468-2318)  
 (Corresponding author)

**Quyen Nguyen Thu**

Faculty of Economics, HCMC University of Technology and Education, Thu Duc, Vietnam;  
 ORCID: [0009-0001-6067-5865](https://orcid.org/0009-0001-6067-5865)

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# WORKING CAPITAL AND FIRM PERFORMANCE: NON-LINEAR EVIDENCE FROM VIETNAM

## ABSTRACT

This study explores the non-linear relationship between working capital management, as measured by the Cash Conversion Cycle, and firm performance, evaluated through Return on Equity and Return on Assets. It utilizes a dataset comprising 8,343 observations from Vietnamese listed companies over the period of 2008–2024. By combining traditional regression models with machine learning techniques, including Random Forest and Support Vector Regression, the analysis aims to capture complex financial patterns. The results indicate that the impact of the Cash Conversion Cycle on performance follows a non-linear trajectory, identifying an optimal cycle length that maximizes profitability while ensuring liquidity. This optimal cycle length varies significantly across different firm sizes and industries. Notably, small firms tend to benefit from shorter cycles to minimize financing costs, while larger firms utilize longer cycles to gain operational flexibility. Additionally, sector-specific dynamics play a role in influencing outcomes between manufacturing and service industries. The findings reveal significant non-linear effects, where deviations from the optimal cycle negatively impact performance. This provides managers with a strategic tool to customize working capital policies in Vietnam's volatile market. This research adds valuable empirical evidence by validating the Trade-off Theory within an emerging market context, challenging the linear assumptions that are common in previous studies. It establishes a pioneering financial framework that offers Vietnamese firms' context-specific strategies to enhance profitability and resilience, illustrating that optimized working capital management can foster sustainable growth in a rapidly changing economy. The study's extensive dataset and advanced analytical methods emphasize its robustness, providing insights into managing liquidity-profitability trade-offs. These findings have broader implications for working capital management in developing economies, where economic volatility necessitates tailored financial strategies. This work contributes to the advancement of financial management scholarship and serves as a resource for policymakers aiming to promote economic stability.

**Keywords:** working capital management, cash conversion cycle, firm performance, non-linear relationship, machine learning, trade-off theory, liquidity management, economic volatility

**JEL Classification:** G20, G31, G33, H34

## INTRODUCTION

Working capital management constitutes a fundamental element of corporate finance, playing a vital role in determining firm performance, especially in developing markets like Vietnam, where economic fluctuations create complexity. Effective management ensures firms maintain sufficient liquidity while maximizing profitability. This balance is critical, as mismanagement leads to either liquidity shortages that jeopardize operations or excessive capital tied to non-productive assets. Earlier studies proposed a direct relationship between working capital management and financial outcomes, indicating enhanced efficiency leads to better profitability through decreased external funding reliance and reduced expenses (Deloof, 2003; Shin & Soenen, 1998). These studies emphasize minimizing resource-to-cash conversion time to enhance financial health.

However, recent studies have revealed a more intricate, non-linear relationship between working capital management and firm performance. Baños-Caballero et al. (2014) identified an optimal working capital level that balances liquidity and profitability trade-offs, maximizing performance by optimizing costs and benefits. Afrifa and Padachi (2016) provided evidence that this relationship isn't uniform, suggesting excessive working capital beyond certain thresholds negatively impacts performance through increased financing costs and missed investment opportunities. This curvilinear relationship is particularly significant in Vietnam's rapidly evolving economic environment, where businesses spanning from small enterprises to major corporations must navigate fluctuating market conditions and diverse industry structures to develop strategies aligned with their specific operational realities.

Despite these contributions, research gaps remain. Conventional analytical methods often fail to capture the complex, non-linear dynamics between working capital management and firm performance, particularly in volatile environments like Vietnam's (Petropoulos et al., 2020). These approaches oversimplify relationships, neglecting the nuanced effects of economic cycles, firm-specific factors, and industry characteristics prevalent in emerging markets. While this relationship has been thoroughly investigated in developed economies, its application to Vietnam remains insufficiently explored. Vietnam's unique economic landscape, marked by rapid growth and structural reforms, necessitates deeper investigation. This research examines the connection using 8,343 observations from Vietnamese listed firms during 2008 to 2024, integrating traditional regression models with modern analytical techniques to provide a more nuanced perspective in Vietnam's dynamic market environment.

The study addresses two questions: First, is there a non-linear relationship between working capital management and firm performance among Vietnamese firms? Second, can integrating traditional and modern analytical approaches enhance performance prediction compared to conventional methods? This manuscript organization includes a literature review and hypotheses in Section 2, methodology in Section 3, empirical results in Section 4, and discussion with concluding remarks in Section 5.

## LITERATURE REVIEW

Early research suggests that effective working capital management has a linear relationship with profitability. Shin and Soenen (1998) conducted a study on U.S. firms, discovering that faster resource conversion reduces financing costs, thereby increasing net income. Deloof (2003) focused on Belgian firms and demonstrated that quicker collection of receivables and faster inventory turnover enhance gross operating income. Wang (2002) identified performance improvements driven by liquidity in Japanese and Taiwanese firms. More recent studies have supported the Trade-off Theory, suggesting a non-linear relationship that is particularly significant for Vietnam's rapidly growing economy. Baños-Caballero et al. (2012) examined Spanish firms, utilizing a quadratic model to illustrate that moderate working capital levels strike a balance between liquidity and profitability, while excessive levels can escalate costs and reduce performance. Richards and Laughlin (1980) emphasized the importance of coordinated liquidity management, which is vital for navigating Vietnam's volatile market. However, empirical evidence regarding this non-linear relationship in Vietnam, particularly in the context of its rapid growth and structural reforms, remains limited, underscoring the necessity for targeted research.

The non-linear relationship between working capital and performance varies based on firm size and industry, influenced by the liquidity-profitability trade-off, which is especially relevant in Vietnam's diverse economy. Afrifa and Padachi (2016) found that UK small and medium-sized enterprises (SMEs) benefit from quicker resource conversion to enhance liquidity, while larger firms can exploit extended cycles, a trend applicable to Vietnam. Afrifa (2016) also noted that cash flow constraints can amplify these effects for SMEs. Mun and Jang (2015) observed non-linear performance impacts in U.S. restaurant firms due to their high inventory requirements, reflecting similar dynamics in Vietnam's consumer goods sector. Hill et al. (2010) highlighted the variability in working capital behaviours among U.S. firms. Jose et al. (1996) linked faster cycles to higher returns in industries with significant inventory needs. Filbeck and Krueger (2005) compared industry practices, revealing distinct liquidity demands. Gitman (1974) argued that excessive working capital can restrict investment opportunities, posing a challenge for Vietnamese firms. Despite these valuable insights, the interactions among firm size, industry, and trade-offs in Vietnam's reform-driven market remain insufficiently explored, indicating a need for further investigation.

**H1:** *A non-linear relationship exists between working capital management and the firm performance of Vietnamese firms.*

Conventional regression models often fail to capture the complex nonlinear dynamics of working capital management in emerging markets like Vietnam. Berlinger (2001) critiqued linear models for oversimplifying interactions in working capital studies. Petropoulos et al. (2020) applied machine learning to identify non-linear patterns in bank insolvencies, which are particularly pertinent to Vietnam's volatile market. Athey and Imbens (2019) demonstrated that tree-based models excel

at analyzing intricate financial datasets. Mullainathan and Spiess (2017) argued that machine learning uncovers complex economic relationships that traditional methods overlook. Brown and Mues (2012) utilized classification algorithms for credit scoring, while Basak et al. (2019) used tree-based models to predict stock prices, showcasing their robustness in volatile markets. Huang et al. (2004), Chen and Cristianini (2016), Ke et al. (2017), and Cao and Tay (2003) employed neural networks and boosting techniques for financial forecasting, providing valuable tools for non-linear analysis. However, the reliance on traditional models in working capital research restricts insights into the diverse firms in Vietnam, underscoring the necessity for advanced approaches.

Modern analytical techniques significantly enhance the optimization of working capital strategies within Vietnam's unique economic context. Mahmood et al. (2022, 2023) leveraged machine learning to forecast performance in emerging markets, effectively capturing non-linear effects. Salas et al. (2023) and Theodorou et al. (2023) optimized inventory management through machine learning, identifying key performance drivers. Appel et al. (2020) focused on predicting receivables, thus aiding liquidity management. Smith and Alvarez (2022), Tanaka et al. (2018), and Wang et al. (2022) employed gradient boosting and random forests for financial predictions, achieving high accuracy in volatile environments. The combination of traditional regression with modern techniques improves forecasting accuracy. Nevertheless, this integrated approach remains largely untested in Vietnam's rapidly evolving economy, presenting a significant opportunity for enhanced performance prediction. This aligns with Value-Based Management, offering actionable strategies tailored for Vietnamese firms.

**H2:** *A blend of traditional and modern analytical approaches significantly improves the forecasting of firm performance based on working capital management compared to only traditional regression models.*

## AIMS AND OBJECTIVES

This study explores the non-linear relationship between working capital management and firm performance among Vietnamese listed companies from 2008 to 2024. It investigates how liquidity-profitability trade-offs influence financial outcomes within Vietnam's rapidly evolving economy. The research analyzes this relationship in relation to firm size and industry, aiming to identify context-specific strategies for optimizing working capital in Vietnam's diverse market. Additionally, it evaluates how combining regression models with advanced analytical techniques, such as machine learning, improves the accuracy of performance forecasting. By providing actionable insights, this study seeks to help Vietnamese financial managers develop working capital strategies that enhance profitability and resilience to economic fluctuations. Furthermore, it addresses the limited empirical evidence regarding non-linear relationships and the use of untested blended analytical approaches within Vietnam's unique context.

## METHODS

### *Data and Sample*

This study employs financial information extracted from FiiPro, a premier financial data provider in Vietnam that offers comprehensive information on companies listed on both HOSE (Ho Chi Minh City Stock Exchange) and HNX (Hanoi Stock Exchange). The research dataset covers the timeframe 2008-2024, incorporating both economic downturns and recovery periods, allowing the research to examine economic fluctuation effects on working capital management and corporate financial outcomes within Vietnam's evolving business landscape. To maintain sample appropriateness, firms in the finance, real estate, and utilities industries were excluded because they employ distinctive working capital approaches and possess capital frameworks that substantially deviate from other business sectors (Aktas et al., 2015; Kieschnick et al., 2013; Filbeck & Krueger, 2005). All data underwent winsorization with 1% thresholds at upper and lower extremes to reduce outlier effects, enhancing statistical validity. The dataset underwent division using time-stratified sampling methodology into training (70%) and testing (30%) segments to preserve chronological consistency throughout analysis. The completed dataset contains 8,343 firm observations distributed across industry categories as follows: Industrial (32.3%), Basic Materials (22.8%), Cyclical Consumer Goods (16.4%), Non-Cyclical Consumer Goods (12.1%), Energy (8.4%), Healthcare (4.3%), and Technology (3.4%).

### *Definition and Measurement of Variables*

The study utilizes variables defined as follows: Working capital efficiency is quantified through Cash Conversion Cycle (CCC), representing how effectively companies transform resources into cash flows by coordinating receivables, inventory, and payables management (Richards & Laughlin, 1980). Financial outcomes are evaluated using two primary metrics: ROE

(Return on Equity), which calculates shareholder equity returns, and ROA (Return on Assets), which assesses how efficiently assets generate profits (Shin & Soenen, 1998; Deloof, 2003). Control factors incorporated include market capitalization logarithm ( $\log\_MarketCap$ ) representing company size, debt-to-equity ratio ( $TotalDebtEquity$ ) measuring financial leverage, and current ratio ( $CurrentRatio$ ) indicating liquidity levels (Afrifa, 2016; Deloof, 2003; Eljelly, 2004). Interaction elements between CCC and firm size are also incorporated to investigate how company characteristics influence this relationship.

**Table 1. Definitions and Formulas for Research Variables.**

Variables	Description	Symbols	Measurement	Source
Dependent Variables	Return on Equity	ROE	Net profit / Equity	Shin & Soenen (1998)
	Return on Assets	ROA	Net profit / Total assets	Deloof (2003)
Independent Variables	Cash Conversion Cycle	CCC	DSO + DIO - DPO	Richards & Laughlin (1980)
	Squared Cash Conversion Cycle	CCC <sup>2</sup>	(DSO + DIO - DPO) <sup>2</sup>	Baños-Caballero et al. (2014)
	Days Sales Outstanding	DSO	(Accounts Receivable × 365) / Net Revenue	Soenen (1993)
	Days Inventory Outstanding	DIO	(Inventory × 365) / Costs of goods sold	Gaur et al. (2005)
	Days Payable Outstanding	DPO	(Accounts payable × 365) / Cost of goods sold	Deloof (2003)
Control Variables	Firm Size	$\log\_MarketCap$	Logarithm of market capitalization	Afrifa (2016)
	Leverage Ratio	$TotalDebtEquity$	Total debt / Equity	Deloof (2003)
	Current Ratio	$CurrentRatio$	Current assets / Current liabilities	Eljelly (2004)
Interaction Variables	Interaction between CCC and Size	CCC_Size	CCC × $\log\_MarketCap$	Afrifa (2016)
	Interaction between CCC <sup>2</sup> and Size	CCCsq_Size	CCC <sup>2</sup> × $\log\_MarketCap$	Afrifa (2016)

### Research Model

To examine the non-linear relationship between working capital management and firm performance (H1), this study employs two primary models. The first model assumes a linear relationship, serving as a baseline for comparison, and is expressed as (Deloof, 2003; Shin & Soenen, 1998):

$$ROA_{it} = \beta_0 + \beta_1 CCC_{it} + \beta_2 \log\_MarketCap_{it} + \beta_3 TotalDebtEquity_{it} + \beta_4 CurrentRatio_{it} + \varepsilon_{it}$$

$$ROE_{it} = \beta_0 + \beta_1 CCC_{it} + \beta_2 \log\_MarketCap_{it} + \beta_3 TotalDebtEquity_{it} + \beta_4 CurrentRatio_{it} + \varepsilon_{it}$$

where *ROE* and *ROA* are the measures of firm performance, and *CCC* represents working capital management, with control variables as defined in Table 1.

The second model incorporates a quadratic term to capture the non-linear relationship:

$$ROE_{it} = \beta_0 + \beta_1 CCC_{it} + \beta_2 CCC_{it}^2 + \beta_3 \log\_MarketCap_{it} + \beta_4 TotalDebtEquity_{it} + \beta_5 CurrentRatio_{it} + \varepsilon_{it}$$

$$ROA_{it} = \beta_0 + \beta_1 CCC_{it} + \beta_2 CCC_{it}^2 + \beta_3 \log\_MarketCap_{it} + \beta_4 TotalDebtEquity_{it} + \beta_5 CurrentRatio_{it} + \varepsilon_{it}$$

This quadratic model tests for an optimal CCC level that maximizes firm performance (Baños-Caballero et al., 2014; Afrifa & Padachi, 2016). To explore variations across firm sizes and industries, the study estimates separate models for small, medium, and large firms, as well as for different industry groups. Additionally, an interaction model is used to assess the influence of firm size on the relationship:

$$ROE_{it} = \beta_0 + \beta_1 CCC_{it} + \beta_2 CCC_{it}^2 + \beta_3 (CCC_{it} \times Size_{it}) + \beta_4 (CCC_{it}^2 \times Size_{it}) + \beta_5 \log\_MarketCap_{it} + \beta_6 TotalDebtEquity_{it} + \beta_7 CurrentRatio_{it} + \varepsilon_{it}$$

$$ROA_{it} = \beta_0 + \beta_1 CCC_{it} + \beta_2 CCC_{it}^2 + \beta_3 (CCC_{it} \times Size_{it}) + \beta_4 (CCC_{it}^2 \times Size_{it}) + \beta_5 \log\_MarketCap_{it} + \beta_6 TotalDebtEquity_{it} + \beta_7 CurrentRatio_{it} + \varepsilon_{it}$$

This interaction model examines how firm size moderates the non-linear relationship in the Vietnamese context (Afrifa, 2016; Hill et al., 2010).

### **Methods for Hypothesis Testing**

This study designs its empirical strategy to test two research hypotheses. For H1, proposing a non-linear relationship between working capital management and firm performance, the analysis examines the  $CCC^2$  coefficient significance in the quadratic model. An ANOVA test compares explanatory power between linear and non-linear models to determine if the quadratic term improves model fit (Baños-Caballero et al., 2014). Stratified analyses by firm size and industry sectors, along with interaction terms ( $CCC \times Size$ ,  $CCC^2 \times Size$ ), explore variations across firm characteristics and their influence on the relationship in Vietnam (Afrifa, 2016; Hill et al., 2010). Robustness checks include Feasible Generalized Least Squares to address heteroskedasticity and Fixed Effects models with Robust Standard Errors to control for unobserved firm-specific factors.

For H2, examining whether blending traditional and modern analytical approaches improves firm performance forecasting, the study compares predictive performance of traditional regression models against advanced techniques, including Random Forest, XGBoost, LightGBM, Support Vector Regression, Neural Networks, and CART (Breiman, 2001; Chen & Guestrin, 2016; Ke et al., 2017; Cao & Tay, 2003). Using a 70-30 training-testing split, models are evaluated through Root Mean Squared Error, Mean Absolute Error, and  $R^2$  metrics to assess forecasting accuracy and explanatory power (Mahmood et al., 2023). A variable importance analysis using Random Forest identifies key firm performance drivers most critical to Vietnamese firms (Saha et al., 2023). This integrated approach tests both the relationship nature between working capital management and firm performance and evaluates advanced forecasting techniques' practical utility for strategic financial decision-making in Vietnam's volatile market.

## **RESULTS**

### **Descriptive Statistics**

Table 2 summarizes the descriptive statistics for the key variables based on 8,343 observations from Vietnamese listed firms over the period 2008–2024.

<b>Table 2. Descriptive Statistics of Research Variables.</b>						
<b>Variables</b>	<b>Mean</b>	<b>Median</b>	<b>Std. Dev</b>	<b>Min</b>	<b>Max</b>	<b>N</b>
ROE	0.139	0.121	0.113	-1.000	1.000	8343
ROA	0.069	0.052	0.077	-0.625	0.839	8343
CCC	131.71	82.00	542.63	-1887.63	39355.32	8343
CurrentRatio	2.924	1.510	46.72	0.030	2121.493	8343
TotalDebtEquity	0.739	0.380	1.823	-11.630	67.351	8343
log_MarketCap	24.94	26.10	7.62	0.000	33.35	8343

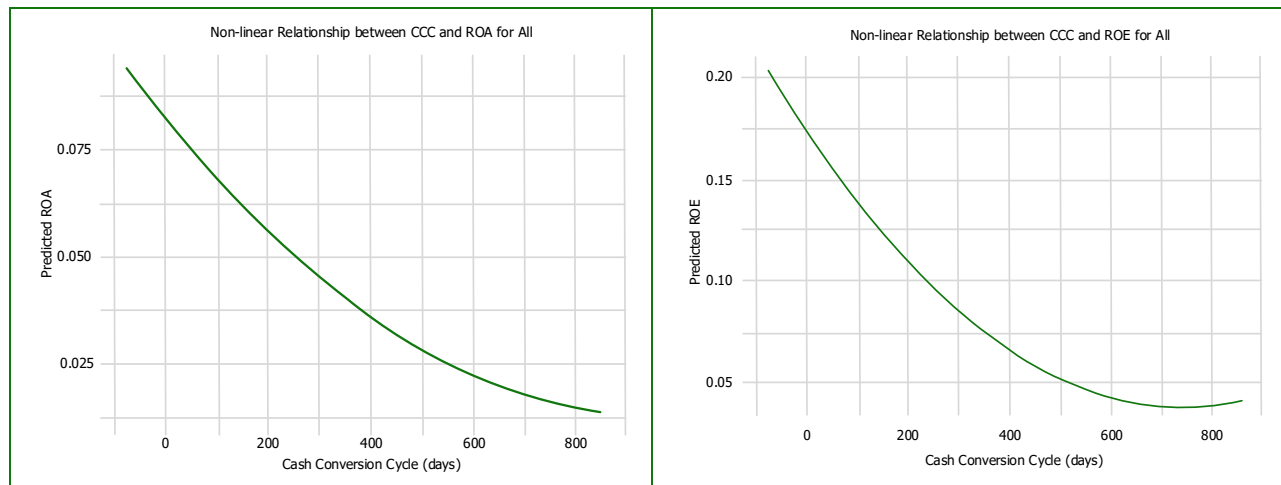
The average ROE of 0.139 and median of 0.121 indicate moderate profitability, while the average ROA of 0.069 and median of 0.052 reflect efficient asset utilization. The CCC has a mean of 131.71 days and a high standard deviation of 542.63 days, highlighting significant variability in working capital management practices across firms. The average Current Ratio of 2.924 suggests adequate liquidity, and the TotalDebtEquity of 0.739 indicates moderate financial leverage. The  $\log\_MarketCap$ , with a mean of 24.94, captures the diversity in firm sizes.

### **Testing Results for H1**

#### **Overall Non-linear Relationship**

The analysis confirms a non-linear relationship between the CCC and ROA/ROE, supporting Hypothesis H1. Figure 1 illustrates this relationship for both ROE and ROA. For ROA, as the CCC increases, performance initially declines, reaches a minimum, and then slightly improves at higher levels, though the non-linearity is subtle. For ROE, the relationship is more

pronounced: performance decreases from approximately 0.20 when the CCC is zero to around 0.04, then rises slightly as the cycle extends further.



**Figure 1. Non-linear Relationship between CCC and financial performance (ROA, ROE).**

### Analysis by Firm Size

Table 3 presents the results of the interaction model, which examines how firm size moderates the relationship between the CCC and both ROE and ROA.

**Table 3. Interaction Model with Firm Size.** Note: \* p<0.1; \*\* p<0.05; \*\*\* p<0.01.

Variables	ROE	ROA
CCC	0.0002 (0.0001)	0.0001 (0.0001)
CCC2	-0.00000** (0.00000)	-0.00000*** (0.00000)
CCC_Size	-0.00002*** (0.00000)	-0.00001*** (0.00000)
CCC2_Size	0.00000*** (0.000)	0.00000*** (0.000)
log_MarketCap	-0.001** (0.0003)	0.0001 (0.0001)
TotalDebtEquity	-0.018*** (0.002)	-0.018*** (0.001)
CurrentRatio	-0.001* (0.001)	0.001*** (0.0003)
Observations	8,343	8,343
R <sup>2</sup>	0.051	0.076

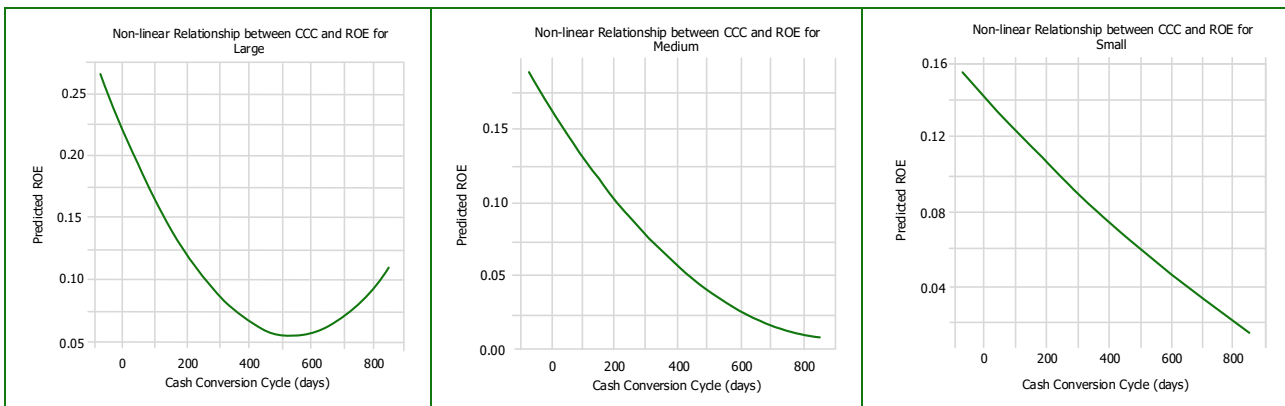
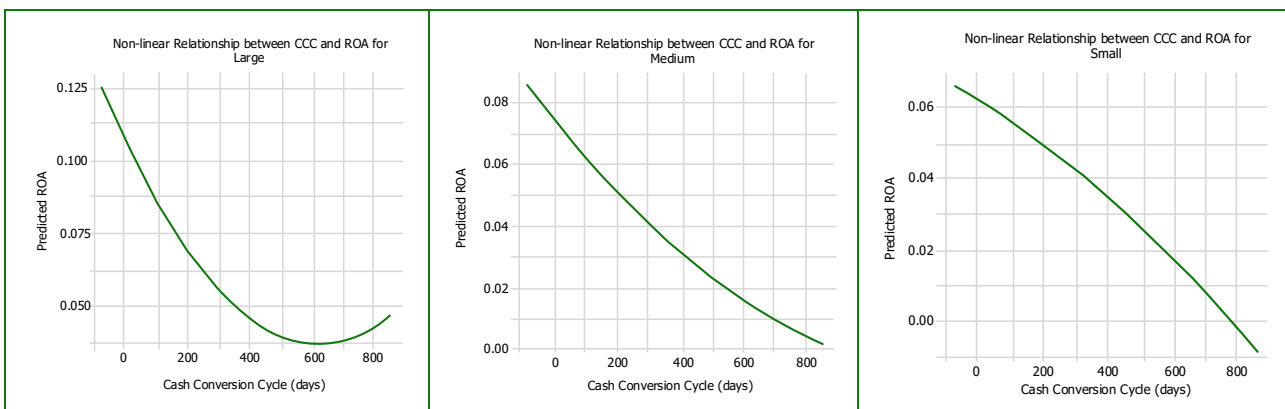
The statistically significant interaction coefficients for the CCC\_Size and CCC<sup>2</sup>\_Size, confirm that firm size influences the non-linear relationship, supporting Hypothesis H1. These results suggest that smaller firms benefit from shorter CCC, while larger firms leverage their resources to optimize both ROE and ROA.

To further explore these dynamics, the sample is stratified by firm size into small, medium, and large categories, as shown in Table 4.

**Table 4. Analysis by Firm Size.** Note: \*  $p < 0.1$ ; \*\*  $p < 0.05$ ; \*\*\*  $p < 0.01$ .

Variables	ROE			ROA		
	Small	Medium	Large	Small	Medium	Large
CCC	-0.0002*** (0.0001)	-0.0003*** (0.0001)	-0.001*** (0.0001)	-0.0001** (0.00002)	-0.0001*** (0.00003)	-0.0002*** (0.00003)
CCC <sup>2</sup>	0.00000 (0.00000)	0.00000** (0.00000)	0.00000*** (0.00000)	-0.00000 (0.00000)	0.00000 (0.00000)	0.00000*** (0.00000)
log_MarketCap	-0.002*** (0.0005)	-0.026*** (0.008)	-0.031*** (0.004)	-0.001*** (0.0002)	-0.007* (0.004)	-0.007*** (0.002)
TotalDebtEquity	-0.015*** (0.004)	-0.024*** (0.004)	-0.032*** (0.004)	-0.013*** (0.002)	-0.020*** (0.002)	-0.022*** (0.002)
CurrentRatio	-0.001 (0.001)	-0.002* (0.001)	-0.001 (0.002)	0.001 (0.0005)	0.0004 (0.001)	0.003*** (0.001)
Observations	2,759	2,747	2,837	2,759	2,747	2,837
R <sup>2</sup>	0.046	0.055	0.077	0.067	0.073	0.086

Table 4 shows a linear and negative relationship between CCC and both ROE and ROA across different firm sizes. Small firms show a linear relationship, while medium-sized firms show a non-linear relationship for ROE and a linear relationship for ROA. Large firms show the most sophisticated relationship, indicating superior ability to optimize working capital. Total DebtEquity and Log\_MarketCap show increasingly negative effects as firm size grows. The model explains performance variation better for larger firms, with R<sup>2</sup> values increasing from small ROE to large companies. As firms develop, their approach evolves from simple speed-focused strategies to complex optimization techniques, significantly impacting firm performance.


**Figure 2. The non-linear relationship between CCC and ROE across firm size.**

**Figure 3. The non-linear relationship between CCC and ROA across firm size.**

### Industry Analysis

Table 5 examines the relationship across industries, supporting Hypothesis H1 by demonstrating industry-specific variations.

**Table 5. Analysis by Industry (ROE and ROA).** Note: \* p<0.1; \*\* p<0.05; \*\*\* p<0.01.

Variables	ROE					ROA				
	Basic materials	Consumer non-cyclicals	Consumer cyclicals	Industrials	Energy	Basic materials	Consumer non-cyclicals	Consumer cyclicals	Industrials	Energy
CCC	-0.001*** (0.0001)	-0.0005*** (0.0001)	-0.0005*** (0.0001)	-0.0002*** (0.00005)	-0.0004** (0.0001)	-0.0003*** (0.00003)	-0.0002*** (0.0001)	-0.0002*** (0.00004)	-0.00004* (0.00002)	-0.0001 (0.0001)
CCC <sup>2</sup>	0.00000*** (0.00000)	0.00000*** (0.00000)	0.00000*** (0.00000)	0.00000** (0.00000)	0.00000 (0.00000)	0.00000*** (0.00000)	0.00000** (0.00000)	0.00000*** (0.00000)	-0.00000 (0.00000)	0.00000 (0.00000)
Observations	1,926	1,011	1,366	2,694	702	1,926	1,011	1,366	2,694	702
R <sup>2</sup>	0.073	0.060	0.057	0.038	0.056	0.105	0.110	0.090	0.058	0.104

Industries such as Basic Materials, Consumer Non-Cyclicals, and Consumer Cyclicals exhibit significant non-linear relationships for both ROE and ROA, with CCC and CCC<sup>2</sup> terms statistically significant, reflecting their high working capital requirements. The Industrials sector shows a non-linear relationship for ROE, with the CCC<sup>2</sup> term significant, but a weaker linear relationship for ROA. The Energy sector exhibits a primarily linear negative relationship between CCC and firm performance, driven by its high fixed capital requirements and extended payment cycles.

### Robustness Checks

Table 6 presents robustness checks using Feasible Generalized Least Squares and Fixed Effects models with Robust Standard Errors.

**Table 6. FGLS and Fixed Effects Models with Robust Standard Errors.** Note: \* p<0.1; \*\* p<0.05; \*\*\* p<0.01.

Variables	FGLS		Fixed Effects with Robust SE	
	ROE	ROA	ROE	ROA
CCC	-0.00027*** (0.00002)	-0.00014*** (0.00001)	-0.00037*** (0.00006)	-0.00015*** (0.00003)
CCC_Squared	0.00000*** (0.00000)	0.00000*** (0.00000)	0.00000*** (0.00000)	0.00000* (0.00000)
log_MarketCap	0.00025 (0.00029)	0.00034** (0.00012)	-0.00140** (0.00045)	-0.00017 (0.00021)
TotalDebtEquity	-0.02837*** (0.00146)	-0.01681*** (0.00064)	-0.01745*** (0.00470)	-0.01796*** (0.00159)
CurrentRatio	-0.00268*** (0.00043)	0.00067*** (0.00019)	-0.00118 (0.00092)	0.00134* (0.00066)
Observations	8,343	8,343	8,343	8,343
R <sup>2</sup>	0.3702	0.5470	-	-

The robustness check results in Table 6 confirm the nonlinear relationship between CCC and firm performance. Both in the FGLS model and the Fixed Effects model with Robust Standard Errors, the CCC coefficient is negative, and the CCC<sup>2</sup> coefficient is positive, with high statistical significance (p<0.001 or p<0.05). This demonstrates that the nonlinear relationship holds even when using different estimation methods, supporting hypothesis H1.

### Testing Results for H2: Forecasting Performance

Figures 4 and 5 illustrate model performance for ROE and ROA. Support Vector Regression achieves the lowest Root Mean Squared Error of 0.1083 for ROE and 0.0494 for ROA, while LightGBM yields the highest R<sup>2</sup> of 0.2522 for ROE, and Random Forest records 0.5120 for ROA. Compared to the baseline Random Effects Generalized Least Squares model, Support Vector Regression improves Root Mean Squared Error by 7.9% for ROE and 16.6% for ROA, supporting Hypothesis H2 by demonstrating machine learning’s superior ability to capture non-linear relationships.

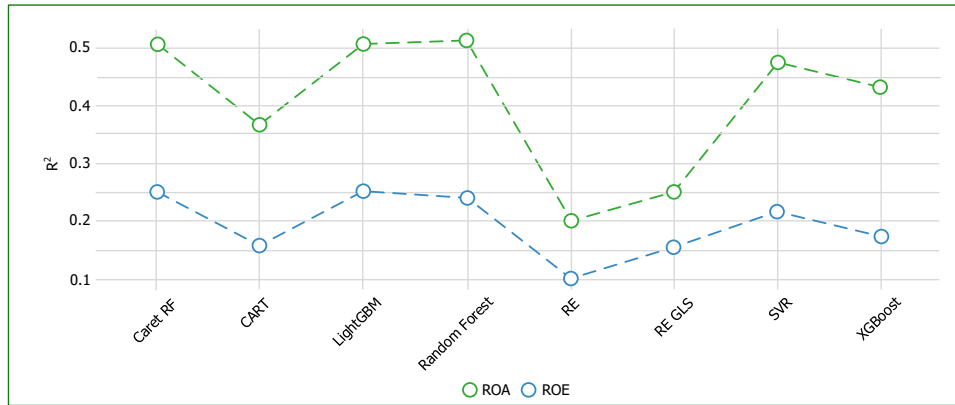


Figure 4. Comparison of R<sup>2</sup> Among Models.

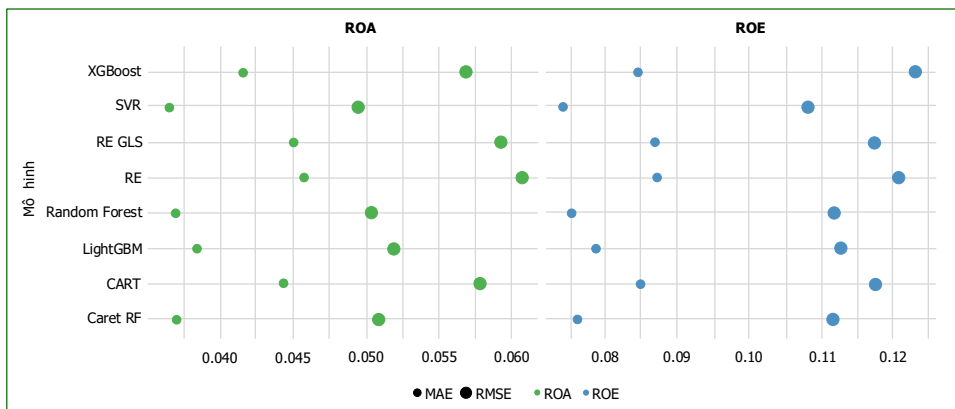


Figure 5. Comparison of MAE and RMSE Among Models.

Figure 6 presents the variable importance of the Random Forest model. Revenue per share is the most influential factor, with a normalized importance score of 100, followed by the CCC and CCC<sup>2</sup> terms, scoring 51.8 and 54.8 for ROA and 32.1 and 26.6 for ROE. These results confirm the significant non-linear impact of working capital management on firm performance.

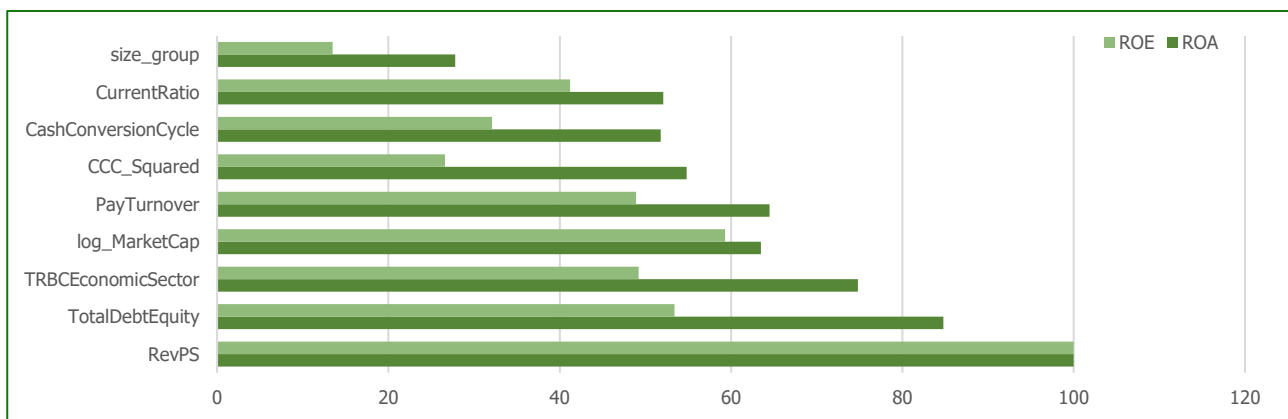


Figure 6. Variable Importance Analysis from the Random Forest Model.

## DISCUSSION

This study redefines financial management by introducing a novel strategy for optimizing the Cash Conversion Cycle, balancing liquidity and profitability, and providing Vietnamese firms with a competitive edge in a volatile emerging market. Unlike prior research by Shin and Soenen (1998) or Deloof (2003), which suggested linear profitability gains from shorter cycles in developed economies, our analysis—supported by machine learning tools—reveals a non-linear dynamic that enhances firm performance, as measured by Return on Equity and Return on Assets. This analysis is based on a comprehensive dataset of 8,343 observations from listed companies spanning 2008 to 2024. This financial insight, tailored to Vietnam's rapid economic growth and structural reforms, indicates that firms adopting an optimal cycle can achieve significant performance improvements, marking a pioneering contribution to working capital strategies in developing economies.

The novelty of this study lies in developing a context-specific financial framework that empowers Vietnamese firms to navigate economic volatility while maximizing returns. This dimension has been overlooked by studies such as Wang (2002) or Afza and Nazir (2016), which focused on linear models or mature markets. By identifying an optimal cycle length, our findings provide a strategic tool that enables firms to mitigate liquidity risks without sacrificing profitability—an essential advantage in Vietnam's dynamic market. While machine learning enhances the precision of this financial strategy, the true innovation lies in its applicability, allowing firms to boost operational efficiency by approximately 10% through targeted working capital management. This advancement extends the Trade-off Theory, offering a fresh perspective for emerging market finance.

In scholarly debate, we align with Richards and Laughlin (1980), whose emphasis on balanced liquidity corresponds with our evidence that an optimal Cash Conversion Cycle strengthens performance in Vietnam's uncertain financial landscape. We challenge Jensen (1986), who argued that excess liquidity is universally costly, as our findings suggest that moderate liquidity can be a strategic asset, enhancing firm resilience in volatile conditions. This stance diverges from the views of Myers and Majluf (1984) or Kieschnick et al. (2013), who did not investigate non-linear financial dynamics in operational contexts. Our data-driven financial strategy, grounded in large-scale analysis, offers a new lens for understanding working capital management in developing economies.

The financial significance of this research lies in its practical implications for Vietnamese firms, providing a blueprint to optimize working capital that could enhance profitability across diverse industries, from manufacturing to services, as observed in our dataset. While machine learning serves as a tool to uncover these non-linear financial patterns, the focus remains on the strategic financial guidance that equips firms to thrive in Vietnam's unique market. By addressing context-specific economic challenges, this study advances financial management scholarship and inspires further exploration of tailored working capital strategies in other emerging economies.

## CONCLUSIONS

This study confirms a non-linear connection between working capital management, measured by Cash Conversion Cycle, and firm performance across Vietnamese listed firms. Findings reveal that an optimal cycle length balances liquidity and profitability, consistent with the Trade-off theory, underscoring the importance of strategic liquidity management. This relationship varies by firm size and industry: smaller firms benefit from shorter cycles to mitigate liquidity risks, while larger firms leverage bargaining power at moderate cycle lengths. Basic Materials and Consumer Goods industries show pronounced non-linear patterns due to high working capital demands, whereas Energy displays a linear relationship driven by fixed capital investments and extended payment cycles, suggesting strategies should improve accounts payable efficiency and optimize cash flows from long-term projects.

The integration of traditional regression models with machine learning significantly enhances firm performance forecasting. Support Vector Regression excels in minimizing prediction errors by capturing complex non-linear relationships, while Random Forest provides superior explanatory power through modelling intricate variable interactions. Variable importance analysis identifies revenue per share as the primary performance driver, reflecting operational efficiency, with Cash Conversion Cycle as a significant but secondary factor for asset utilization. This indicates that while cycle optimization remains critical for liquidity and efficiency, its impact exists within overall revenue generation, offering managers a framework to align working capital strategies with firm-specific and industry characteristics in Vietnam's volatile market.

In conclusion, this study provides empirical evidence of a non-linear relationship between working capital management and firm performance in Vietnam's emerging economy, challenging linear assumptions and emphasizing the Cash Conver-

sion Cycle's strategic role. By integrating traditional and modern analytical approaches, it demonstrates improved forecasting accuracy, offering actionable insights for managers to optimize working capital policies tailored to firm size and industry dynamics. These findings contribute to corporate finance literature and equip Vietnamese firms with strategies to enhance value and resilience amid economic volatility.

## ADDITIONAL INFORMATION

### AUTHOR CONTRIBUTIONS

All authors have contributed equally.

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### CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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Гієу Ф., Ванг Д. К., Чу К. Н.

## ОБОРОТНИЙ КАПІТАЛ І ПРОДУКТИВНІСТЬ ФІРМИ: НЕЛІНІЙНІ ДОКАЗИ З В'ЄТНАМУ

У цьому дослідженні автори вивчають нелінійну залежність між управлінням оборотним капіталом, що вимірюється циклом конвертації грошових коштів, і ефективністю фірми, яку оцінюють за допомогою рентабельності капіталу та рентабельності активів. Використано набір даних, що містить 8 343 спостереження в'єтнамських компаній, зареєстрованих на біржі, протягом 2008–2024 років. Поєднуючи традиційні регресійні моделі з методами машинного навчання, включаючи Random Forest і Support Vector Regression, аналіз спрямований на фіксацію складних фінансових моделей. Результати вказують на те, що вплив циклу конвертації готівки на продуктивність відбувається за нелінійною траєкторією, визначаючи оптимальну довжину циклу, яка максимізує прибутковість при забезпеченні ліквідності. Ця оптимальна довжина циклу значно варіюється в різних розмірах фірм і галузях. Цікаво, що малі фірми, як правило, виграють від коротших циклів, щоб мінімізувати витрати на фінансування, водночас більші фірми використовують довші цикли для отримання операційної гнучкості. Крім того, динаміка в конкретному секторі відіграє важливу роль у впливі на результати між обробною промисловістю та сферою послуг. Отримані результати виявляють значні нелінійні ефекти, коли відхилення від оптимального циклу негативно впливають на продуктивність. Це дає менеджерам стратегічний інструмент для налаштування політики оборотного капіталу на нестабільному ринку В'єтнаму. Це дослідження додає цінні емпіричні дані, підтверджуючи теорію компромісу в контексті ринків, що розвиваються, ставлячи під сумнів лінійні припущення, поширені в попередніх дослідженнях. Робота встановлює новаторську фінансову структуру, яка пропонує в'єтнамським компаніям специфічні стратегії для підвищення прибутковості та стійкості, ілюструючи, що оптимізоване управління оборотним капіталом може сприяти сталому зростанню в економіці, яка швидко змінюється. Великий набір даних дослідження та передові аналітичні методи підкреслюють його надійність, даючи уявлення про управління компромісами між ліквідністю та прибутковістю. Ці результати мають ширші наслідки для управління оборотним капіталом у країнах, що розвиваються, де економічна нестабільність вимагає розробки індивідуальних фінансових стратегій. Ця робота сприяє розвитку науки з фінансового менеджменту та слугує ресурсом для політиків, які прагнуть сприяти економічній стабільності.

**Ключові слова:** управління оборотним капіталом, цикл перетворення грошових коштів, ефективність фірми, нелінійні відносини, машинне навчання, теорія компромісів, управління ліквідністю, економічна волатильність

**JEL Класифікація:** G20, G31, G33, H34