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Article

Panel regression of industrial sustainability indicators: Two-step system GMM to robust estimation

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Abstract: This study aims to scrutinize specific long-term sustainability industrial indicators in Thailand as a representative of an emerging economy. The study uses a Bloomberg database comprising all Thai listed companies on the Stock Exchange of Thailand from 2013 to 2023. The research employs a two-step Generalized Method of Moments (GMM) statistics to assess the enduring impact on industrial sustainability. These results provide consistent, significant and positive relationships between asset turnover and sales with all industrial sustainability. The results additionally reveal that some other factors may moderate industrial sustainability but reveal the GDP growth rate and institutional shareholders are less likely to be corporate sustainability to all indicators. The results provide insight into valuable guidance to management teams, financial statements' users, investors and other stakeholders on designing effective operations and investment strategies to improve sustainability.

Keywords: sustainability; GMM estimation; financial reporting; Thailand

1. Introduction

Recently, the sustainability concept has become increasingly critical consideration in all industrial sectors (Amouzesh et al., 2011; Arora et al., 2018; Fonseka et al., 2012; Pinto, 2020). Despite the complexity of industrial systems and nature of sustainability pose significant challenges in the accurate measurement and interpretation of these indicators. Previous studies have made considerable steps in discovering sustainability practices across various industries. However, several important research gaps or inconsistencies continue. One of the most noteworthy gaps is the lack of industry-specific factors, while some studies fail to provide a detailed comparison across different industrial sustainability. This limitation confines unique challenges that influence sustainability practices in various industries causing a fragmented view of industrial sustainability (Arora et al., 2018; Dogan and Kevser, 2021; Fang et al., 2018). Besides, prior studies have repeatedly ignored to scrutinize the assumptions underlying regression analyses. Especially, problems of autocorrelation and heteroscedasticity. This leads significantly weaken the reliability of findings. The absence creates a research gap in accurately assessing sustainability indicators (Imhanzenobe, 2020). This needs more sophisticated analytical techniques to provide more reliable industrial sustainability.

Another critical gap in the existing literature fails to investigate the combination effect of all important variables such as macroeconomic indicators and institutional factors in the context of corporate sustainability. GDP growth and institutional shareholders are widely recognized as influential factors in shaping corporate governance. However, their roles have not been thoroughly investigated across different industry sustainability. Also, their roles interacting with financial metrics to influence or deter sustainability initiatives remain unclear (Ang et al., 2022; Dogan and Kevser, 2021). Understanding this interaction is crucial for explaining effective sustainability strategies that are adapted to the specific requirements and challenges of different industries.

To direct these identified gaps, this study introduces significant variables and advanced statistical analysis across various industries to observe corporate sustainability indicators. In addition, a panel regression analysis with a two-step Generalized Method of Moments (GMM) estimation technique to overcome the methodological limitations of previous research is employed. The two-step system GMM estimation method addresses issues related to endogeneity, unobserved heterogeneity, and measurement errors, which are common challenges in panel data analysis. Together with methodological concerns, this study critically examines the role of GDP growth, institutional shareholders and financial metrics on corporate sustainability across different industries. Opposing to conventional prospects, the findings reveal that these factors do not commonly serve as significant indicators of all industrial sustainability. The study contributes not only existing academic literature and practical recommendations on industrial sustainability which benefit stakeholders and policymakers.

To summarize, this study aims to achieve: (1) identify and validate the most significant indicators of industrial sustainability across different sectors; (2) quantitatively analyze the impact of various factors on industrial sustainability using advanced econometric techniques; and (3) provide insights and recommendations for management teams, policymakers and industry stakeholders to enhance sustainability practices. By systematically addressing the identified research gaps, this study seeks to contribute to a more comprehensive understanding of industrial sustainability development and guide effective decision-making to realize it.

The organization of this paper is carefully structured as follows. Section 2 provides an in-depth literature review of the variables relevant to this study; Section 3 introduces the conceptual framework, establishing the basis for the research. Section 4 details the research methodology that is utilized; Section 5 thoroughly examines the study’s findings. Finally, Section 6 presents a comprehensive conclusion, outlines the study’s limitations, and suggests directions for future research on this topic. Lastly, the Appendices emphasize the importance of the statistical analyses conducted.

2. Literature review

2.1. Corporate sustainability concept

The Stock Exchange of Thailand (SET) prioritizes sustainable capital market development by strengthening stakeholders’ ability to adapt to economic, social, and environmental changes. Since 1994, SET has focused on enhancing corporate governance (CG) among listed companies, aligning with international standards to ensure responsible growth, financial stability, and sustainability. SET’s sustainability policy promotes economic growth under the auspices of strong corporate governance, effective risk management, and responsible operations so that the wider society and the environment benefit. The policy also encourages extending sustainability efforts across the supply chain, ensuring positive outcomes for both the organization and its broader community (SET, 2024).

Sustainable Growth Rate (SGR), first familiarized by Higgins (Higgins, 1977) is a financially based indicator that highlights the alignment of internal growth capability with financial stability, making it very important for strategic decision-making. Unlike broad frameworks like Environment, Social, and Governance (ESG), Global Reporting Initiative (GRI), Triple Bottom Line (TBL), or Corporate Social Responsibility (CSR), SGR provides a concrete, quantifiable metric directly related to a firm's resource efficiency and financial management. Its combination of important financial measures, including as profit retention, asset usage, and leverage, gives a unified method to ensuring sustainable development without overextending external finance. This focus on internal sustainability is particularly suited to industries with capital-intensive operations or competitive market contexts. Thus, adopting SGR provides for a detailed evaluation of financial sustainability and development potential across diverse businesses. In addition, the concept highlighted the importance of accounting practices in establishing the maximum growth rate which a company enables to achieve from retained earnings. The financial metrics reflect SGR concept include profit margins, asset efficiency, financial policies, and earnings retention rates. The SGR formula states as ROE x (1-dividend payout ratio) (Amouzesh et al., 2011; Pinto, 2020). This concept allows a company to set the maximum achievable growth without external financing. Subsequently, studies have expanded Higgins' concept (Fonseka et al., 2012). Arora et al. (2018) stated that SGR is a valuable instrument to harmonize growth intentions with financial resources to make more effective strategic planning and control.

Prior studies have adopted the SGR model in different industries. For example, Lockwood and Prombutr (2010) investigated the association between the SGR and stock returns and found out that the model was considered as practical application in investment strategies. Mukherjee and Sen (2017) found that SGR can guide financial planning and risk management in the banking industry. Moreover, Manaf et al. (2018) adapted the SGR model to specific regulatory environments (i.e., Shariah-compliant firms) demonstrated that the SGR concept was flexible in addressing diverse financial practices. Gardner et al. (2011) applied the SGR model to analyze Coca-Cola's financial performance resulting in the applicability of traditional financial models to modern corporate situations. Similarly, Huang and Zhang (2015) examined the SGR of listed companies and found that these companies had growth potential. Furthermore, Pasalao et al. (2024) found that free cash flow positively correlates SGR, especially in smaller firms with fewer female board members.

In summary, the SGR model introduced by Higgins (Higgins, 1977) remains a critical tool in providing corporate sustainability valuable. Its adaptability across industries and regulatory environments, along with its integration of key financial and operational factors, makes it an enduring framework for evaluating financial health and guiding strategic growth decisions.

2.2. Independent variables

The relationship between financial ratios, ownership structure, and macroeconomic indicators like GDP has grown extensive consideration on corporate sustainability. Financial ratios like liquidity, profitability, and financial policies provide as essential indicators of financial health of companies. Ownership structure, especially institutional shareholders effects corporate governance and strategic decisions, resulting in long-term sustainability systems. Furthermore, GDP reflects broader economic environments directly influencing a firm's sustainability. Therefore, this study intends to explore how these independent variables affect corporate sustainability. The results should be considered as knowledge body on corporate sustainability determinants.

2.2.1. Informative value of financial reporting on corporate sustainability

Financial ratios have been considered as important tools in evaluating sustainable financial conditions. Recently, once corporate sustainability has been considered important, financial ratios can offer a company's long-term viability and its ability to pursue sustainable practices. Previous studies have approached financial ratios to measure corporate sustainability. Ratios such as the liquidity ratio, debt to equity ratio, return on assets (ROA), and asset turnover ratio have been re-examined in the context of their implications for long-term sustainability (Alarussi, 2021; Ajeigbe et al. 2021; Pham et al., 2021). This study adopts a range of financial ratios discussed below.

Asset turnover ratio is considered as management capability to manage its assets. Sustainable practices persuade long-term resource planning which can positively affect asset turnover. Prior research suggests that companies with higher asset turnover potentially leading to corporate sustainability. However, the impact of asset turnover on sustainability varies across industries (Ajeigbe et al., 2021). Sustainability attempts have been learned to influence financial leverage, including debt to equity ratio. Previous studies have shown that equity investors prefer a lower cost of equity. Nonetheless, debt investors could consider as riskier. This dual effect suggests that while equity financing becomes more attractive, the debt-to-equity ratio may not be negatively affected by higher cost of debt (Hinaya and Ellili, 2021; Mamilla, 2019; Mumu et al., 2019; Nor et al., 2020). Free cash flow (FCF) suggests remaining cash after paying operating expenses and capital investments and often used as a sustainability indicator. The relationship between FCF and corporate sustainability has been a hybrid finding. On one hand, FCF positively impacts sustainability by enabling continuing investment Wen (2017), on the other hand, over FCF potentially overinvest in ineffective scheme, potentially weakening sustainability Park and Jang (2013). Sales are considered as a crucial indicator of corporate sustainability because they are needed to reinvest in sustainable attempts like investment in R&D, sustainable initiatives (NasiruKaoje and Babangida, 2020). Earnings per share (EPS) is valued as corporate sustainability. High or steadily growing EPS suggests a company's ability to sustain operations, attract investors, investor confidence, raise stock prices and finance sustainability scheme. This study intends to scrutinize the ability of the above financial ratios on corporate sustainability (Maryana and Carolina, 2021).

Several previous studies have explored the relationship between financial performance and sustainability, highlighting the importance of financial ratios as indicators of sustainable practices. For instance, Soytus (2019) underscores the positive impact of sustainability initiatives on financial performance, although these initiatives may be costly for highly productive firms. Alarussi (2021) finds that profitability, working capital, and productivity positively correlate with sustainability in Malaysian companies, while liquidity and tangibility show negative relationships, emphasizing the need for efficient financial management. NasiruKaoje and Babangida (2020) demonstrate that larger firms with higher sales growth in the Nigerian oil and gas sector are more likely to engage in sustainability reporting, which enhances financial performance and contributes to GDP growth. Similarly, Ajeigbe et al. (2021) demonstrate a positive association between key financial ratios and firm value in Nigerian companies, suggesting that robust financial practices support sustainability and stable GDP growth. Meanwhile in the Swedish scenario, Pham et al. (2021) detect a positive link between sustainability practices and financial performance, although the results for Tobin's Q are inconclusive. The study recommends adherence to sustainability indices and GRI Standards to improve financial performance.

This research highlights the integrating sustainable considerations into financial analysis. By using financial ratios as sustainability indicators, companies can align their economic goals with sustainability objectives, encouraging sustainable development.

2.2.2. Internal factors: Institutional shareholders and firm age

Institutional shareholders

Ownership structure plays a vital role in determining both corporate governance and sustainability consequences. Especially, institutional shareholders focus on long-term sustainability practices because they put pressure on companies with environmental, social, governance (ESG) issues. Furthermore, these shareholders typically prioritize long-term value creation, pushing firms to integrate sustainability into their core operations. (Choi et al., 2020; Fang et al., 2018). Studies inconsistently found the association between ownership structure and sustainability. Institutional and foreign shareholder potentially correlate with corporate sustainability. However, family-owned firms are more likely to prioritize short-term performance rather than sustainability aims (Dogan and Kevser, 2021). Corporate social responsibility (CSR) representing corporate sustainability indicators are less significant in family ownership firms (Kim et al., 2018), while institutional shareholders prefer lower financial leverage for sustainable financial health (Choi et al., 2020). In addition, more diversified ownership structures are typically associated with more sustainability outcomes than those of in concentrated ownership which delay sustainability objectives (Yilmaz et al., 2022). In summary, the literature suggests that institutional and diversified ownership structures generally affect corporate sustainability.

Firm age

Firm age influences corporate sustainability in several keyways. Older firms benefit from years of experience helping them forge effective sustainability practices. This experience enables them to adapt more efficiently to market changes and regulatory requirements, and strong relationships with stakeholders. These relationships facilitate better communication and collaboration on sustainability initiatives. Such businesses are more willing to invest in projects that may not yield immediate returns but are beneficial in the long run. However, Badulescu et al. (2018) found the age of a firm is not a convincing factor in determining its level of corporate social responsibility (i.e. corporate sustainability. Maryana and Carolina (2021) discovered that firm size, leverage, firm age, media visibility, and profitability significantly influence sustainability. However, they were found to have no significant impact on sustainability when considered individually. Leverage and firm age negatively and significantly affected SR disclosure, whereas profitability had a positive and significant effect. Fadilah et al. (2022) discovered that both firm size and firm age positively influence sustainability reporting. They also found that the economic dimension of sustainability reporting positively impacts earnings management, while the environmental dimension negatively affects it. However, the social dimension of sustainability reporting has no effect on earnings management. Rwakihembo et al. (2023) demonstrated a positive correlation between the age of a firm and its financial performance. Their findings indicated that firm age explains 14% of the variation in financial performance among private limited companies in Uganda. The study advises managers to focus on factors that ensure the longevity of their businesses by developing sound investment and operational strategies aligned with the various stages of their firm's life cycle. Digdowiseiso (2023) found that the current ratio had a negative and statistically insignificant relationship with corporate social responsibility (CSR). Conversely, there was a negative relationship between firm size and CSR. Additionally, firm size did not influence the relationship between the current ratio and CSR or between firm age and CSR. The study also revealed that firm size weakened the connection between good corporate governance and CSR.

In sum, while firm age can provide advantages in sustainability practices, its influence is nuanced and dependent on various factors, including firm size, profitability, and governance structures. Understanding these dynamics is essential for managers and policymakers aiming to improve sustainability outcomes across different stages of a firm's life cycle.

2.2.3. Economic factors: GDP

Gross Domestic Product (GDP) is a widely recognized indicator of economic health, yet its role in measuring and achieving sustainability is a topic of ongoing debate. The literature reveals a complex relationship between GDP growth and sustainability, highlighting both benefits and challenges. Perrings and Ansuategi (2000) revisit the Brundtland Report, discussing how both poverty-driven resource depletion and affluence-driven pollution affect environmental sustainability. Their study finds that while economic growth initially degrades the quality of the environment, it may improve as incomes rise, suggesting a nuanced relationship between GDP and environmental resilience. Carrera and Vergara (2012) emphasize the interconnectedness of economic policies and sustainability, particularly in the context of foreign currency debt and fiscal policy sustainability. Similarly, Li and Lin (2019) focus on emerging economies, finding that despite strong GDP growth, limited innovation and slow sustainable total-factor productivity growth threaten sustainable development. This underscores the need to balance economic growth with environmental and technological considerations.

Alternative economic models are explored by Sevenfelt (2019), who proposes scenarios for achieving sustainability without prioritizing GDP growth, such as collaborative economies and local self-sufficiency. Suggested here is that diverse economic strategies could achieve sustainability without relying solely on GDP. Michael et al. (2019) examine Ghana, finding a positive correlation between GDP growth and sustainable development indicators, yet they stress the importance of tailored policies to achieve holistic sustainability. Wilczyński and Kołoszycz (2021) assess dairy farms in the European Union, showing that economic size and financial management practices are crucial for economic sustainability, indicating that sustainable agricultural practices can support GDP growth. In Imhanzenobe (2020) identifies key financial practices in the manufacturing sector that support sustainable GDP growth, emphasizing the importance of financial stability and efficiency. Adrangi and Kerr (2022) analyze the association between GDP and the United Nations' Sustainable Development Goals (SDGs) in BRIC countries, concluding that GDP growth alone does not ensure sustainable development. They also advocate for a broader focus on various development indicators. Finally, Gajdosova (2023) critiques GDP as an inadequate measure of development, calling for multi-dimensional indicators that integrate economic, social, and ecological systems. This perspective aligns with the broader literature that suggests re-evaluating the role of GDP in modern economies to better align economic growth with sustainability objectives.

In summary, while GDP growth is linked to improvements in living standards, it also presents challenges for environmental sustainability and long-term development. The literature advocates for alternative economic models and multi-dimensional indicators so that GDP growth with sustainability goals, particularly in emerging economies is better balanced.

3. Conceptual framework

The above literature review gives rise to a research opportunity for this study. **Figure 1** suggests that financial reporting variables (debt to equity, free cash flow, sales, and earnings per share), internal factors (institutional shareholders and age) directly influence corporate sustainability. Additionally, the external economic environment, represented by GDP growth, impacts corporate sustainability. This integrated approach highlights the multifaceted influences on corporate sustainability, emphasizing the need for companies to manage both internal and external factors effectively to achieve sustainable growth.

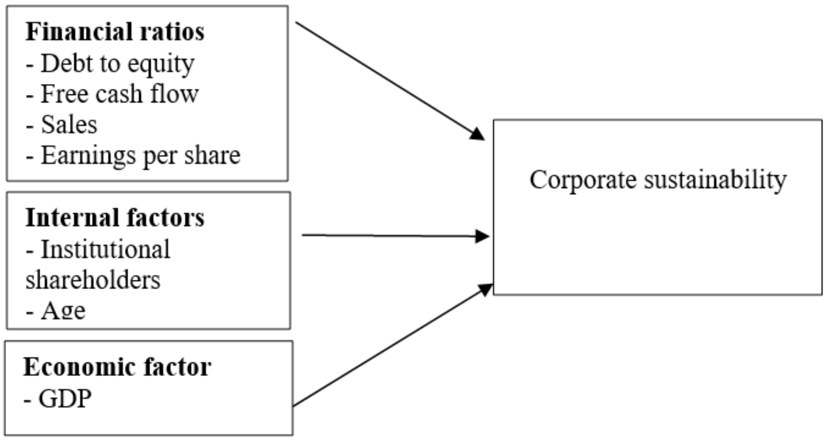

Figure 1. Conceptual framework.

4. Research methodology

4.1. Dataset and statistical analysis

The population includes all listed companies on the Stock Exchange of Thailand (SET). Data was sourced from the Bloomberg database, covering the years 2013 to 2023. The analysis focuses on various industrial sectors of companies listed on SET, categorized into eight sectors: agro (836 observations), consump (682 observations), fincial (902 observations), indus (1474 observations), propcon (2178 observations), resourc (847 observations), service (2145 observations), and tech (726 observations). A significant effort in this study was devoted to meticulously gathering data to minimize errors in the dataset. Financial figures from the data set were carefully extracted from the Bloomberg database, without relying on manual data collection. Following data collection, a random check of the database information against the hard copies of annual reports confirmed the high accuracy of the data.

4.2. Measurements for the variables

Table 1 presents detailed information on the measurement of various study variables, both dependent and independent, along with references to previous studies that have used these measurements.

Table 1. Measurement of study variables.

Variables	Acronym	Measurements	Previous studies
Dependent variable			
Sustainable growth rate	SGR	ROE × Retention Rate (retention = 1 − dividend payout ratio)	Amouzesh et al. (2011); Arora et al. (2018); Altahtamouni et al. (2022); Fonseka et al. (2012); Pinto (2020); Pasalao et al. (2024)
Independent variable			
Asset turnover	AST	Sales to total assets	Ajeigbe et al. (2021)
Debt to equity	DE	Debt to equity	Fonseka et al. (2012); Hinaya and Ellili (2021); Mukherjee and Sen (2018); Mamilla (2019); Mumu et al. (2019); Nor et al. (2020); Rahim (2017)

Table 1. (*Continued*).

Variables	Acronym	Measurements	Previous studies
Free cash flow	FCF	Cash flow from operation–Capital expenditures	Aburisheh et al. (2022); Fu et al. (2022); Sapuan et al. (2021); Tee (2023)
Sales	SAL	Total sales	NasiruKaoje and Babangida (2020)
Earnings per share	EPS	Net income to number of registered shares	Maryana and Carolina (2021)
Institutional shareholders	INS	% of institutional shareholders to total outstanding shares	Choi et al. (2020); Dogen, (2021); Fang et al. (2018); Yilmaz et al. (2022)
Age	AGE	Number of years from commencement date	Badulescu (2018); Carolina (2021); Digdowiseiso (2023); Fadilah et al. (2022); Maryana and Rwakihembo et al. (2023)
Growth of Gross Domestic Product	GDP	% increase (decrease) of GDP from last year	Adrangi and Kerr (2022); Carrera and Vergara (2012); Gajdosova (2023); Imhanzenobe (2020); Li and Lin (2019); Michael et al. (2019); Sevenfelt (2019); Wilczyński and Kołoszycz (2021)

4.3. Model specifications

In order to achieve the study's objectives, the analysis formulates the Equation as presented here:

$$\text{SGR}it = \beta 0 + \beta 1ASTit + \beta 2DEit + \beta 3FCFit + \beta 4SALit + \beta 5EPSit + \beta 6INSit + \beta 7AGEit + \beta 8GDPit + \varepsilon it$$

4.4. Data validity and reliability

The process of collecting data is crucial given that the quality of data is paramount. It is therefore essential to assess both reliability and validity. In this research, emphasis was placed on validity, which entailed the thorough and accurate version of all pertinent information, while reliability was concerned with the consistency of the data, as noted by Zikmund et al. (2012). The data were sourced from the Bloomberg database and financial statements published by the Thai Securities and Exchange Commission (SEC). Bloomberg is recognized as a dependable source, fulfilling the accuracy standards required for Thai listed companies, thereby ensuring the study's content validity. The purpose of evaluating validity is to confirm the precision of the connection between the measurement and the attribute it is intended to measure. Several investigations were meticulously conducted to verify that the data met the assumptions necessary for regression analysis. The subsequent sections detail these assumption tests.

Figure 2 illustrates that panel regression combines cross-sectional data with time series, where the same cross-sectional units are observed at different points in time. Essentially, panel data consists of observations from the same individuals over a specific period. Given T time periods (t = 1, 2, ..., T) and N individuals (i = 1, 2, ..., N), the total number of observation units in panel data equals N multiplied by T.

The Fixed Effect Model differs from the Common Effect Model but still operates under the ordinary least squares principle. The assumption that each cross-section and time period has a constant intercept is deemed less realistic, necessitating more sophisticated models to capture the differences. Fixed effects allow for variations between individuals by accommodating different intercepts. To assess a Fixed Effect Model with varying intercepts between individuals, the dummy variable technique is employed, often referred to as the Least Squares Dummy Variable (LSDV) technique.

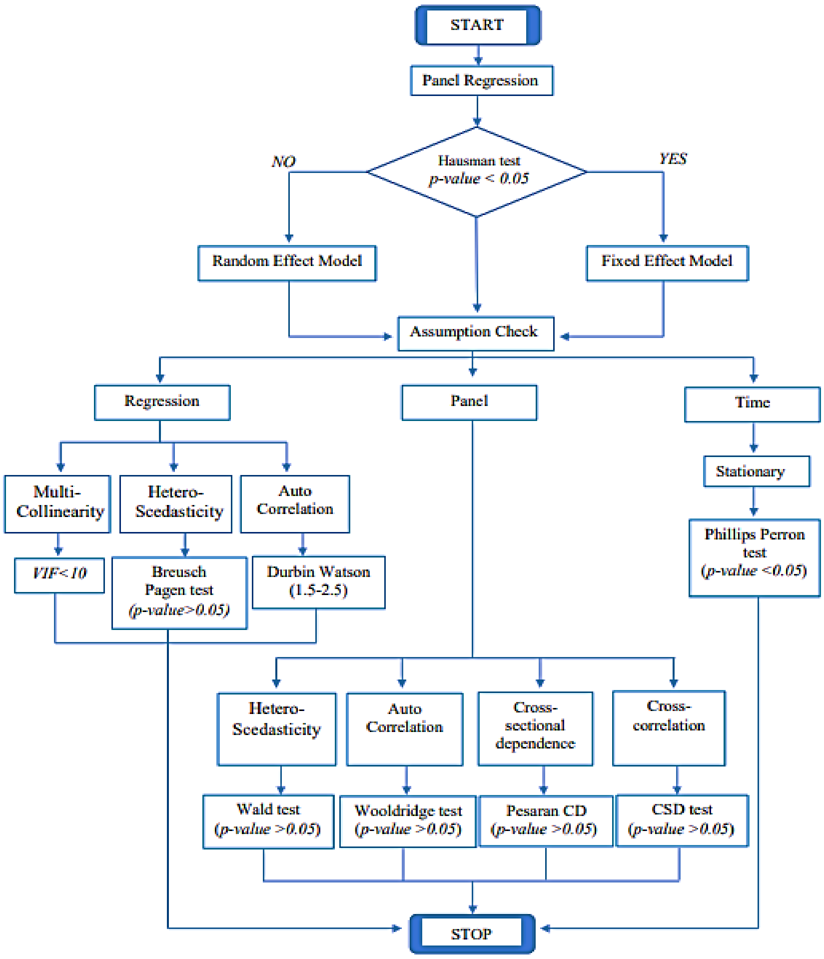

Figure 2. Panel regression analysis.

The Random Effect Model (RE) serves to estimate panel data where interference variables might be correlated across time and among individuals. Unlike the Fixed Effect Model, the Random Effect Model addresses variations in intercepts through the error terms specific to each entity. One of the main advantages of the Random Effect Model is its capacity to eliminate heteroscedasticity. This model is also referred to as the Error Component Model (ECM) or the Generalized Least Squares (GLS) technique. Fundamentally, the Random Effect Model differs from both the Common Effect and Fixed Effect models, primarily because it employs maximum likelihood or generalized least squares principles rather than ordinary least squares (Wooldridge, 2010).

The Hausman test is a statistical method used to determine whether the Fixed Effect or Random Effect Model is more appropriate. The results are interpreted as follows: H0 (p-value > 0.05) suggests selecting the Random Effect Model, while H1 (p-value < 0.05) supports the Fixed Effect Model, according to Greene (2002). The following assumption tests are conducted. Multicollinearity, a phenomenon where two or more predictors are highly correlated, leading to increased standard errors and potentially insignificant variables when they should be significant, is tested using tolerance and the variance inflation factor (VIF < 10) (Hair et al., 2010). Heteroscedasticity, which refers to the non-constant variance of error terms across predictor values, is tested using the Breusch-Pagan Test (p-value > 0.05) in linear regression, and the Wald Test (p-value > 0.05) in panel data analysis.

Autocorrelation, or the correlation between the values of the same variables across different observations, can lead to underestimated standard errors of the coefficients and higher R-squared values. In linear regression, this is tested using the Durbin-Watson statistic (1.5–2.5) (Kutner et al., 2005), while the Wooldridge test (p-value > 0.05) is used for panel data (Wooldridge, 2010). Cross-sectional dependence (CSD) tested using the Pasaran CD test, checks whether residuals are correlated across entities, as this can bias test results. The null hypothesis of no correlation is rejected when the p-value is below 0.05, as explained by Chudik and Pesaran (2013).

After conducting the regression analysis, as depicted in **Figure 2**, it was identified that autocorrelation and heteroscedasticity were present in the fixed effects outcomes. Consequently, further analysis was carried out. **Figure 3** demonstrates that the two-step system GMM Estimator combined the dynamic panel model and moment conditions.

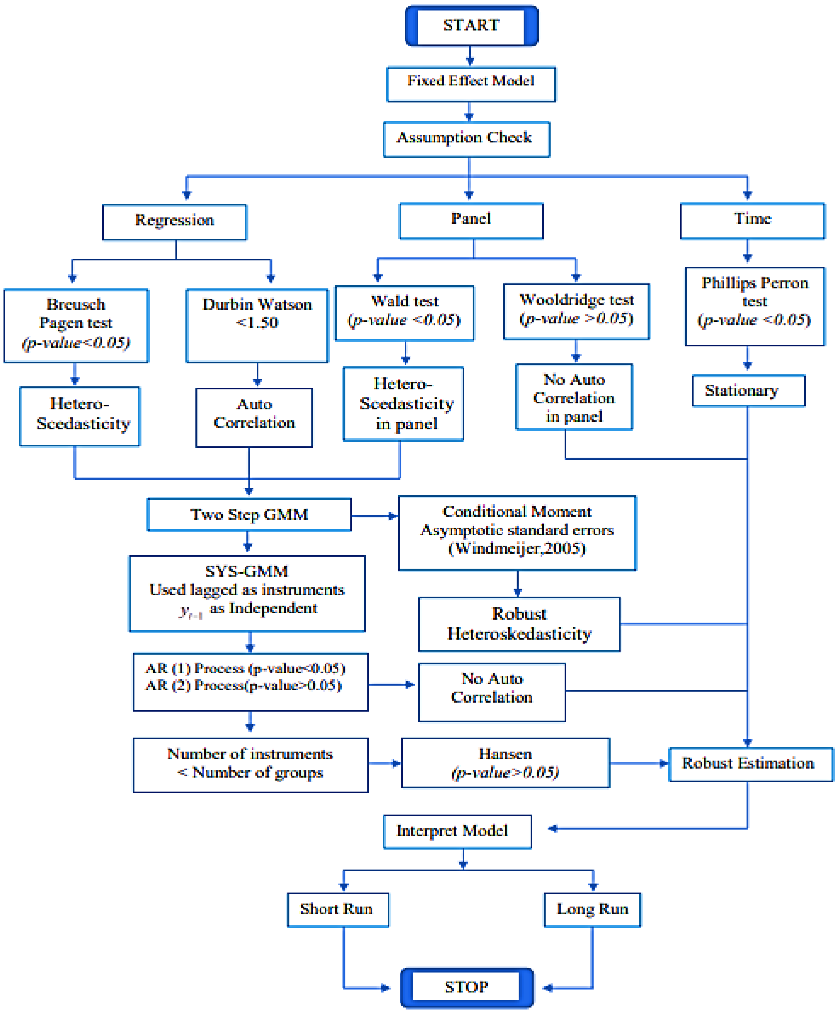

Figure 3. Two-step panel regression analysis.

This study outlines the evolution of GMM estimators for dynamic panel data models as follows. Arellano and Bond (1991) introduced the GMM estimator to tackle endogeneity issues in dynamic panel data models, particularly when lagged dependent variables are used. The Arellano-Bond estimator employs lagged levels of variables as instruments for first-differenced equations, effectively addressing individual-specific effects. However, it encounters problems with weak instruments, especially when dealing with persistent variables. Blundell and Bond (1998) enhance the Arellano-Bond method by resolving the weak instrument problem. The System GMM estimator incorporates additional moment conditions, using lagged differences as instruments for the level equations, thereby improving estimation efficiency in scenarios with persistent data or small sample sizes. Blundell et al. (2000) broadened the application of the System GMM estimator to a wider range of empirical contexts, showcasing its practical utility in various economic models. This work highlighted the System GMM's superiority over traditional estimators, particularly in handling endogeneity and boosting efficiency, thus cementing its position as a standard tool in empirical research. Windmeijer (2005) addressed a crucial drawback of the two-step GMM estimator within the System GMM framework, namely the downward bias in standard errors. Windmeijer (2005) introduced a finite-sample correction for the variance of the two-step system GMM estimator, which has since become a standard procedure, ensuring more accurate and reliable statistical inference.

The standard errors presented for the 1-step estimation are robust, based on the heteroscedasticity-consistent variance estimator.

$$\text{Var}(\hat{\gamma})=\text{M}^{-1}(\sum_i W_i Z_i) A_N \hat{V}_N A_N (\sum_i Z_i' W_i)\, M^{-1}$$

where $M = (\sum_i W_i' Z_i) A_N (\sum_i Z_i' W_i)$ and $\hat{V}_N = \text{N}^{-1} \sum_i Z_i' \hat{u}_i \hat{u}_i' Z_i$ with $\hat{u}_i$ the vector of residuals in differences for individual i. Windmeijer (2005) used the standard errors in moment conditions. The 2-step estimation the SYS estimator combines the moment conditions is

$$\begin{pmatrix} \Delta y_t \\ y_t \end{pmatrix} = \alpha \begin{pmatrix} \Delta y_{t-1} \\ y_{t-1} \end{pmatrix} + \begin{pmatrix} \Delta u_t \\ u_t \end{pmatrix}$$

where $\hat{\alpha} = \tilde{\delta} \hat{\alpha}_d + (1 - \tilde{\delta}) \hat{\alpha}_l$ and $\tilde{\delta} = \frac{\hat{\pi}_d' Z_d' Z \hat{\pi}_d}{\hat{\pi}_d' Z_d' Z_d \hat{\pi}_d + \hat{\pi}_l' Z_l' Z_l \hat{\pi}_l}$ see also Blundell et al. (2000) with

$$\text{p}\,\widetilde{lim}\,\delta = \frac{E(\frac{1}{N}\mu_d)}{E(\frac{1}{N}\mu_d) + \frac{\sigma_l^2}{\sigma_d^2} E(\frac{1}{N}\mu_l)}$$

and $\tilde{\delta} \rightarrow 0$ if $\alpha \rightarrow 1$ and /or σ_n^2 / σ_v^2 the absolute bias of the two-step system GMM estimator was less than the absolute biases of the DIF and LEV 2SLS estimators.

In conclusion, these papers collectively represent a significant advancement in the methodology for estimating dynamic panel data models, effectively addressing the challenges of endogeneity, weak instruments, and reliable inference. The System

GMM estimator has become a widely used tool in empirical research across numerous fields.

In conclusion, the two-step system GMM method was selected to mitigate endogeneity concerns stemming from the inclusion of lagged dependent variables and possible simultaneity between explanatory and dependent variables. This method improves efficiency by addressing heteroskedasticity and serial correlation, thus increasing reliability for the dataset. This method is appropriate for panel data with a substantial sample and a limited time length. The complementary approaches such as fixed effects may insufficiently address dynamic effects. However, the two-step system GMM method has limitations, specifically instrument proliferation. The study addresses this by restricting the number of instruments and using the Hansen test to verify validity resulting in robust and reliable results.

5. Data analysis

5.1. Descriptive analysis

Table 2. Descriptive statistics and boxcox transformation (λ).

VARIABLES	Boxcox transformation (λ)								MEAN	SD	MAX	MIN	ZSKEW	ZKUR
	Agro	Consump	Fincial	Indus.	Propcon	Resourc	Service	Tech						
SGR	1.59	1.08	1.54	1.05	0.93	0.81	0.98	1.04	30.49–658.52	5.06–159.47	1564.17	0.10	−0.8–8.49	1.02–16.50
AST	0.44	0.64	−0.12	0.36	−0.04	0.07	0.23	0.19	1.19–0.94	0.03–0.22	1.82	0.08	−0.25–0.98	−5.12–16.2
DE	−0.01	1.20	0.17	0.14	0.25	0.26	−0.02	0.06	0.92–6.64	0.01–1.02	11.49	0.11	−0.63–46.23	−4.49–39.33
FCF	1.07	1.43	0.94	1.28	2.28	0.77	1.04	1.27	0.51–2.20	0.20–0.90	6.23	0.10	−2.65–11.98	−3.2–19.17
SAL	1.02	0.29	0.20	0.49	0.21	0.49	0.37	1.04	1.43–47.29	0.08–5.73	89.47	0.01	2.00–27.30	2.30–52.22
EPS	0.53	0.61	0.77	0.89	0.47	0.43	0.77	0.50	0.68–1.81	0.10–0.25	3.14	0.02	1.87–13.98	1.38–64.30
INS	0.69	0.20	0.92	0.53	0.75	0.64	1.03	0.28	2.16–57.15	0.18–21.98	114.82	1.00	–1.27–0.01	–4.54–16.5
AGE	0.41	1.04	−0.03	1.04	1.04	1.10	1.04	0.89	0.97–10.50	0.02–4.01	17.26	0.11	–17.98–5.2	–3.16–60.69
GDP	0.95	1.00	0.19	0.65	0.48	0.60	0.58	0.91	2.03–146.65	0.18–23.37	232.14	0.05	–8.72–0.85	–3.71–16.5
No. of obs.	594	451	605	1131	1155	605	1122	363						

Table 2 lists all variables across different sectors including Agriculture, Consumptions, Finance, Industrial, Property, Resources, Services, and Technology. For each variable, the following statistics provide the mean, standard deviation (SD), maximum (MAX) and minimum (MIN) values. **Table 2** also indicates ZSKEW, the

skewness of the data, confirming the asymmetry of the distribution and ZKUR, the kurtosis of the data, and the tailedness of the distribution.

The Box-Cox transformation was initially applied to achieve normality in the data distribution. Key observations indicate that post-transformation, the normality of the data is tested using Z-skewness (Zskew) and Z-kurtosis (Zkur). For the data to be normally distributed, the Zskew and Zkur values should lie within the (−1.96, 1.96) range at a 0.05 significance level and (−2.58, 2.58) at a 0.01 significance level (Hair et al., 2010). Also, the sector-wise analysis strongly suggests that, for example, the variable SGR reveals a mean range from 0.81 to 1.59 across different sectors with a maximum value of 1564.17 and a minimum of 0.10, highlighting significant variability. In addition, the study employs Huber's M-Estimator (Menezes et al., 2021). This method is used to check for outliers with a weighting constant of 1.339. Huber's M-Estimator is robust against outliers, providing a more reliable central tendency measure in the presence of anomalies. In summary, the analysis results indicate that the data conforms to normal distribution assumptions, facilitating more accurate and reliable statistical modeling and inference.

5.2. Regression analysis results

The document provides an analysis using the Dynamic Panel Generalized Method of Moments (GMM) or two-step system GMM for panel data to address issues of autocorrelation and heteroscedasticity that were observed in Fixed Effect outcomes as shown in the Appendix. The analysis incorporates a variety of models across different sectors. Each model's significance and implications are described below. The two-step system GMM analysis results are shown in **Table 3** (short-term) and **Table 4** (long-term). It is noted that the explanation of **Table 4** is not described because only the coefficients are different, while the statistically significant level is the same.

Table 3. Panel regression of the two-step system GMM model—short-run.

Variables	Agro	Consump	Fincial	Indus.	Propcon	Resourc	Service	Tech
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
Y_{t-1}	0.232***	0.265***	0.733***	0.445***	0.389***	0.249***	0.492***	0.371***
CONST	3.035	5.336***	3.982**	3.089***	5.773***	9.391***	2.190	−2.091
AST	1.818***	7.987***	1.763*	3.160***	5.648***	1.461***	4.833***	6.181***
DE	−2.768***	−0.618	0.143*	−0.477**	−0.001	1.537***	−0.119	0.628
FCF	6.257***	5.821	0.156	8.715***	2.756***	5.838***	5.156***	−0.095
SAL	0.474***	0.401**	0.265**	0.337*	0.470***	2.446***	0.958**	0.615***
EPS	0.365	7.618***	0.753	2.692**	0.481	−1.598***	−0.728	−2.748
INS	−0.019	−0.032***	−0.008	0.001	0.100***	−0.044**	0.010	−0.009
AGE	−0.215***	−0.071	−1.095	0.089	−0.098***	0.254***	0.506***	−0.227
GDP	0.039***	−0.129***	−0.029**	−0.029	−0.001	−0.137***	−0.051*	0.025
YEAR2014	NS	NS	NS	NS	NS	NS	NS	NS
YEAR2016	NS	NS	NS	1.373**	NS	NS	NS	NS
YEAR2017	NS	NS	NS	NS	NS	NS	NS	NS

Table 3. (*Continued*).

Variables	Agro	Consump	Fincial	Indus.	Propcon	Resourc	Service	Tech
	Coef.	**Coef.**	**Coef.**	**Coef.**	**Coef.**	**Coef.**	**Coef.**	**Coef.**
YEAR2019	NS	NS	1.475*	−1.906**	NS	NS	NS	NS
YEAR2021	NS	NS	NS	1.932***	NS	NS	NS	NS
YEAR2022	NS	NS	NS	−1.533**	NS	NS	NS	NS
YEAR2023	NS	NS	NS	−1.997***	NS	NS	NS	NS
Adj R2	0.873	0.509	0.547	0.463	0.492	0.480	0.568	0.461
Durbin Watson	2.340	1.972	1.906	1.858	1.739	1.679	1.675	1.921
F	43.090	4.350	6.720	5.030	14.5147	2.480	15.377	4.040
HANSEN	0.528	0.974	0.900	0.474	0.324	0.584	0.248	0.995
AR (1)	0.017	0.014	0.001	0.000	0.000	0.030	0.000	0.002
AR (2)	0.845	0.346	0.508	0.961	0.546	0.537	0.069	0.594
No. of observations	432	328	385	927	945	440	918	264
No. of groups	54	41	55	103	105	55	102	33
No. of instruments	44	44	42	53	53	44	53	44

*Significant at level 0.05, **at level 0.01, ***at level 0.001, NS: Not Significant

Table 4. Panel regression of the two-step system GMM model—Long-run.

Variables	Agro	Consump	Fincial	Indus.	Propcon	Resourc	Service	Tech
	Coef.	**Coef.**	**Coef.**	**Coef.**	**Coef.**	**Coef.**	**Coef.**	**Coef.**
Const	NS	7.260***	14.914**	5.566***	9.448***	12.505***	NS	NS
AST	2.367***	10.867***	6.603*	5.694***	9.244***	1.945***	9.514***	9.827***
DE	−3.604***	NS	6.603*	−0.859**	NS	2.047***	NS	NS
FCF	8.147***	NS	NS	15.703***	4.511***	7.774***	10.150***	NS
SAL	0.617***	0.546**	0.993**	0.607*	0.769***	3.257***	1.886**	0.978***
EPS	NS	7.353***	NS	4.850**	NS	−2.128***	NS	NS
INS	NS	−0.044***	NS	NS	0.164***	−0.586**	NS	NS
AGE	−0.280***	NS	NS	NS	−0.160***	0.338***	0.996***	NS
GDP	0.051***	−0.176***	−0.109*	NS	NS	−0.182***	−0.100*	NS
YEAR2014	NS	NS	NS	NS	NS	NS	NS	NS
YEAR2016	NS	NS	NS	2.468**	NS	NS	NS	NS
YEAR2017	NS	NS	NS	NS	NS	NS	NS	NS
YEAR2019	NS	NS	NS	−0.343**	NS	NS	NS	NS
YEAR2021	NS	NS	NS	3.481***	NS	NS	NS	NS
YEAR2022	NS	NS	NS	−2.762**	NS	NS	NS	NS
YEAR2023	NS	NS	NS	−0.366***	NS	NS	NS	NS

*Significant at level 0.05, **Significant at level 0.01, ***Significant at level 0.001, NS: Not significant

In **Table 3**, in the Agro sector, several variables exhibit significant coefficients, indicating their strong influence. The lagged dependent variable (Y_{t-1}) shows a coefficient of 0.232 with a high level of significance ($p < 0.001$), suggesting that past values of the dependent variable are a strong predictor of its current values. The variable AST, with a coefficient of 1.818, is also highly significant ($p < 0.001$), indicating its positive impact on the dependent variable. In contrast, DE has a negative and significant coefficient (−2.768, $p < 0.001$), highlighting its negative effect. Other significant variables include FCF (6.257, $p < 0.001$), SAL (0.474, $p < 0.001$), AGE (−0.215, $p < 0.001$), and GDP (0.039, $p < 0.001$), each contributing uniquely to the model.

For the Consumer sector, the significant lagged dependent variable (Y_{t-1}) with a coefficient of 0.265 ($p < 0.001$) reinforces the importance of historical values in predicting current outcomes. The constant term is also significant (5.336, $p < 0.001$), reflecting a strong baseline effect. AST (7.987, $p < 0.001$) is notably positive and significant, emphasizing its positive influence. However, DE and FCF are not significant, demonstrating its minimal impact in this sector. Other notable significant variables include SAL (0.401, $p < 0.01$), EPS (7.618, $p < 0.001$), INS (−0.032, $p < 0.001$), and GDP (−0.129, $p < 0.001$).

In the Finance sector, the lagged dependent variable (Y_{t-1}) has a substantial coefficient of 0.733 ($p < 0.001$), indicating a strong dependency on past values. The constant term (3.982, $p < 0.01$) and AST (1.763, $p < 0.05$) are significant, revealing their positive influence. DE (0.143, $p < 0.05$) and SAL (0.265, $p < 0.01$) also contribute positively, whereas GDP is negatively significant (−0.029, $p < 0.01$), indicating an adverse effect.

For the Industrial sector, the lagged dependent variable (Y_{t-1}) with a coefficient of 0.445 ($p < 0.001$) and the constant term (3.089, $p < 0.001$) show strong positive significance. AST (3.160, $p < 0.001$) and FCF (8.715, $p < 0.001$) are highly influential, while DE has a negative impact (−0.477, $p < 0.01$). Other significant variables include SAL (0.337, $p < 0.05$) and EPS (2.692, $p < 0.01$).

In the Property sector, significant variables include the lagged dependent variable (Y_{t-1}) (0.389, $p < 0.001$), the constant term (5.773, $p < 0.001$), and AST (5.648, $p < 0.001$). FCF (2.756, $p < 0.001$) and SAL (0.470, $p < 0.001$) are also significant, highlighting their positive effects. The variable INS (0.100, $p < 0.001$) shows positive significance, whereas AGE (−0.098, $p < 0.001$) is negatively significant.

For the Resources sector, the lagged dependent variable (Y_{t-1}), (0.249, $p < 0.001$) and the constant term (9.391, $p < 0.001$) are significantly positive. AST (1.461, $p < 0.001$), DE (1.537, $p < 0.001$), FCF (5.838, $p < 0.001$), and SAL (2.446, $p < 0.001$) contribute positively, while EPS (−1.598, $p < 0.001$) and INS (−0.044, $p < 0.01$) exhibit negative impacts. AGE (0.254, $p < 0.001$) is positively significant, and GDP (−0.137, $p < 0.001$) shows negative significance.

In the Services sector, the lagged dependent variable (Y_{t-1}), (0.492, $p < 0.001$) and AST (4.833, $p < 0.001$) are significantly positive. FCF (5.156, $p < 0.001$) and SAL (0.958, $p < 0.01$) also show positive significance. AGE (0.506, $p < 0.001$) is positively significant, while GDP (−0.051, $p < 0.05$) is negatively significant.

Lastly, the Technology sector shows significant positive effects from the lagged dependent variable (Y_{t-1}), (0.371, $p < 0.001$) and AST (6.181, $p < 0.001$). SAL (0.615, $p < 0.001$) is also positively significant.

Overall, the GMM estimation has effectively addressed the issues of autocorrelation and heteroscedasticity present in the panel data. The significant variables across different sectors provide insights into the key drivers of performance, allowing for more targeted policy and strategy development. The robustness of the GMM models is confirmed through various statistical tests, ensuring reliable and valid results.

Table 4 provides a detailed analysis using the Dynamic Panel Generalized Methods of Moments (GMM) estimation to address issues of autocorrelation and heteroscedasticity in panel data. The Hansen test, a dynamic panel technique, produces results confirming the appropriateness of the instrument variables used, where the number of instruments exceeds the number of groups. The long-run equations derived from the models offer significant insights into various sectors presented below.

$$\text{Long run } \hat{\beta}^*{}_i = \frac{\hat{\beta}_i}{(1-\alpha)} \text{ (Greene, 2002)}$$

5.3. Discussion and implementation

The statistical significance of various independent variables is evident for corporate sustainability across different industry sectors, namely Agriculture, Consumer, Finance, Industrial, Property, Resources, Services, and Techno. The short-term result (**Table 3**) highlights that the previous year's performance (Y_{t-1}) shows a highly significant positive relationship with corporate sustainability across all sectors. This implies that a firm's past performance is a crucial predictor of its current sustainability, reflecting a strong continuity in sustainable practices and outcomes over time. The long-term results show the same as the short-run results.

The significant finding of this study is that asset turnover and sales demonstrate a predominantly positive and significant relationship with corporate sustainability across all sectors. These findings are consistent with previous studies (NasiruKaoje and Babangida, 2020; Ajeigbe et al., 2021). This positive correlation is observed wherein higher efficiency in utilizing assets generally enhances corporate sustainability. Additionally, sales display a consistently positive and significant relationship with corporate sustainability across all sectors. The significant finding underscores the importance of revenue generation in driving sustainability efforts across industries.

Debt to equity ratio shows varied effects on corporate sustainability. In the Agriculture, Consumer, and Finance sectors, there is a significant negative association between debt to equity and corporate sustainability indicating that higher debt relative to equity is detrimental to sustainability. Conversely, in the Property and Resources sectors, a positive relationship is noted, suggesting that higher leverage might enhance sustainability in these industries. Free cash flow is significantly positive in the Consumer, Finance, Industrial, Property, Resources, Services, and Techno sectors. This indicates that higher free cash flow supports corporate sustainability, likely by providing the necessary resources for sustainable practices and investments. Earnings per share (EPS) plays an important role in the Consumer, Industrial, and Techno sectors, but its effects differ. In the Industrial and Techno sectors, higher EPS is positively linked to sustainability, indicating that greater profitability per share helps support sustainable practices. In contrast, in the Consumer sector, higher EPS is negatively associated with sustainability, suggesting that a focus on short-term profit maximization may come at the expense of long-term sustainability efforts.

Institutional shareholders negatively impact on corporate sustainability in the Finance, Property, and Techno sectors. This implies that increased institutional shareholders is more likely to hinder sustainability because of the pressure these shareholders place on companies to prioritize short-term financial returns rather than long-term sustainability goals. Firm age specifies a different influence on industrial sustainability. In the Agriculture, Consumer, and Finance sectors, older firms are more likely to fight with sustainability because they may rely on obsolete practices. On the other hand, older firms in the Industrial and Services sectors seem to perform better sustainability due to benefiting from their experience and existing resources. GDP shows various effects on industrial sustainability. In the Consumer, Finance, and Techno sectors, a significant positive relationship is found, indicating that higher economic growth supports sustainability. However, in the Agriculture, Property, and Resources sectors, the relationship is negative and significant, suggesting that higher GDP might negatively impact sustainability in these industries. The explanation for this is the increased economic activities that strain sustainable practices.

The debt to equity ratio is considered as a crucial financial sustainability. It impacts the ability to undertake sustainable plans, manage financial risks, as well as maintain flexibility for continuing growth. By understanding this relationship, various sectors can enhance their financial frameworks to manage their capital requirements, risk measurements as well as strategic priorities in enhancing growth and sustainability. The diverse implications of the debt-to-equity ratio on sustainability across different industries can be suggested as follows. Industries including resources, property development and construction rely immensely on significant debt due to their capital-intensive manners and extended investment timelines. While leveraging enables the execution of extensive projects, it may impose limitations on adaptability for sustainability plans during periods of economic decline or instability. On the other hand, agriculture, industrial and technology sectors have increased revenue fluctuations and prioritize equity financing to maintain flexibility for innovation and sustainability. Financial institutions may employ heightened leverage; however, they face the perils of systemic instability, which impacts sustainability, especially in times of economic decline. Industrial enterprises strategically navigate debt to maintain their ability to invest in sustainable technologies, all the while ensuring financial stability. The consumer and services sectors demonstrate lower capital demands and primarily intangible assets, leading to a decreased reliance on debt. Nevertheless, in instances where debt levels are high, these corporations may prioritize financial obligations at the expense of social and environmental goals, thereby compromising sustainable initiatives.

5.3.1. Theoretical contribution

The results of this study offer several significant theoretical contributions to the current literature on corporate sustainability. First, the significant relationship identified between sales and corporate sustainability growth expands the understanding of how revenue generation influences a company's ability to maintain and enhance sustainable practices. This understanding enhances current sustainability theories by showing that financial performance indicators, especially sales, play a key role in driving sustainability. Sales not only indicate a company's market position and customer approval but also generate the financial means needed to invest in sustainable technologies, processes, and initiatives.

Second, the study highlights the critical role played by asset turnover in fostering corporate sustainability growth. By establishing a significant relationship between asset turnover and sustainability, this research underscores the importance of operational efficiency and resource utilization in achieving sustainability goals. High asset turnover suggests that a company is effectively consuming its assets to generate revenue, which translates into better financial health and the capability to support long-term sustainable initiatives. This finding integrates operational efficiency into the sustainability discourse, suggesting that companies must focus on optimizing asset use to drive sustainable growth.

Thirdly, the study finds that institutional shareholders and GDP growth are less likely to support corporate sustainability. These outcomes are not in line with Modernization Theory, which typically posits that economic growth (as reflected in GDP growth) should lead to more sustainable practices due to increased resources and societal demands. However, this discrepancy may arise because the impact of corporate sustainability can vary depending on geographical region, industry, or the type of institutional investor. Suggested here is that traditional theories may need to be adapted or refined to account for these context-specific factors.

5.3.2. Policies and practical contribution

For management team

Management teams, including the board of directors and CEOs, should prioritize sales and asset turnover for several compelling reasons. Sales are the primary source of revenue for any company, and strong sales performance directly translates to higher income, which is essential for covering operating costs, investing in growth opportunities, and delivering returns to shareholders. Moreover, consistent sales growth indicates a robust market presence and customer base, reflecting the ability to compete effectively and meet customer demands, which is crucial for long-term sustainability. High sales volumes can: firstly, improve cash flow, reduce reliance on external financing; and secondly, enhance the ability to converge its financial obligations, contributing to overall financial stability and reducing financial risk. Sales figures also constitute a key performance indicator (KPI) that provides insights into the effectiveness of the company's strategies, marketing efforts, and customer satisfaction, helping management identify trends, assess strategy effectiveness, and make informed decisions. In addition, this study find that asset turnover positively relates to corporate sustainability causing to better productivity and cost efficiency. Efficient asset utilization can lower production costs and increase profit margins, providing a competitive edge in the market. Companies that manage their assets well can offer competitive pricing or invest more in innovation and customer service. Investors closely watch asset turnover ratios since they provide insights into management's ability to utilize resources effectively. Strong asset turnover can attract investors by demonstrating that the company is making the most of its investments. High asset turnover ratios are often linked with sustainable business practices and growth potential, indicating that the company can grow without needing disproportionate increases in asset investment, thus supporting long-term sustainability.

For management teams in various sectors

The research indicates sector-specific changes in important factors that influence sustainability across different industries. The agriculture sector's previous performance, asset turnover, and free cash flows highlight the critical role of efficiency and liquidity in the face of revenue risks. Nevertheless, elevated debt levels adversely affect sustainability owing to income unpredictability. The focus on earnings per share and asset turnover in the consumer sector underscores the dependence on profitability and effective asset management. Institutional investing exhibits a detrimental impact, indicating prudent investor conduct. Simultaneously, the finance industry exhibits significant path dependency and underscores the beneficial effects of asset turnover and judicious loan utilization, reconciling regulatory mandates with sustainability. The industrial sector's emphasis on asset turnover and free cash flows underscores the necessity for liquidity and efficiency, whereas increased indebtedness adversely impacts sustainability. In the real estate industry, effective asset use and institutional investment promote sustainability; yet age and debt may provide hazards during economic recessions. In the resources industry, asset turnover and strategic debt use enhance sustainability, yet environmental problems and profitability limitations indicate a necessity for prudent capital allocation. The services industry depends significantly on asset efficiency and free cash flow for expansion, with established enterprises demonstrating more sustainability. Ultimately, the technology sector has a favorable influence from historical performance and asset turnover, highlighting innovation and expansion via effective asset usage.

For outside parties

Creditors should consider that higher sales indicate the ability to generate income and meet financial obligations, while high asset turnover shows efficient resource management, reducing lending risks. Investors should value sales and asset turnover because higher sales cause higher profits and dividends, while higher asset turnover improves profit margins and returns on investment. Employees and other stakeholders also benefit from the indicators because they support job security, continued business, and economic contributions. Policymakers must enforce sustainability rules and regulation to promote long-term corporate sustainability alongside economic growth.

6. Conclusion

This study identifies long-term indicators of corporate sustainability across various industries, using a dataset of the companies listed on the Stock Exchange of Thailand from 2013 to 2023 and employing the two-step system GMM technique. Key findings indicate that the previous year's performance (Y_{t-1}) is a significant predictor of current sustainability across all sectors, showing strong continuity in sustainable practices. Asset turnover and sales demonstrate a predominantly positive and significant relationship with corporate sustainability, emphasizing the importance of efficient asset utilization and revenue generation. The debt-to-equity ratio has varied effects; it negatively impacts sustainability in the Agriculture, Consumer, and Finance sectors but positively influences the Property and Resources sectors. Free cash flow positively supports sustainability in multiple sectors by providing resources for sustainable practices. Earnings per share (EPS) positively affects sustainability in the Industrial and Technology sectors but negatively in the Consumer sector, possibly due to short-term focus on making profits. Institutional shareholders show a negative relationship with sustainability in the Finance, Property, and Technology sectors, suggesting pressure for short-term returns. Firm age has mixed effects: older firms in the Agriculture, Consumer, and Finance sectors face sustainability challenges, while those in the Industrial and Services sectors perform better in terms of sustainability. GDP growth has a positive relationship with sustainability in the Consumer, Finance, and Technology sectors, but a negative impact in the Agriculture, Property, and Resources sectors. This is likely due to increased economic activities putting sustainability-related practices under strain. These insights are valuable for management teams and stakeholders in formulating policies and strategies to enhance sustainability in their operations and investments.

Limitations and further studies

The study opens new avenues for future research. The significant relationships identified suggest the need for further investigation into other financial metrics and their impact on sustainability. Future studies could explore the longitudinal effects of sales and asset turnover on sustainability, examine these relationships in different industry contexts, or consider additional variables that may moderate or mediate these effects.

Future studies may investigate particular proxies within each sector to improve sustainability indicators. In the agricultural sector, the weather risk index may assess the influence of weather fluctuations on financial stability. The brand score in the consumer sector can evaluate the impact of brand reputation on sustainability programs. The capital adequacy ratio in the financial sector offers the impact of regulatory stability compliance. The supply chain efficiency index in the industrial sector may assess the flexibility and sustainability of supply chains. The green building certification score in the property sector can assess the use of sustainable construction norms. The carbon intensity ratio in the resources sector helps assess the efficacy of carbon reduction initiatives. The employee retention rate in the services industry can evaluate the influence of human capital management on sustainability. Finally, the ratio of RandD investment in the technology industry may assess the efficacy of innovation initiatives in promoting sustainability.

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Appendix

After the study set all variables as shown in the model specification, firstly, OLS was performed; however, the outcome did not fit as required when using the regression assumption. Secondly, the study moved on to test whether the model should fit into the Fixed Effect or Random Effect. The analysis found that autocorrelation and heteroscedasticity were still evident and this is explained as follows.

Table A1 provides detailed statistical tests and their findings across different sectors. Here is a descriptive explanation of the significant findings. VIF values range from 1.008 to 1.593 across all sectors. These values are within the acceptable range (VIF < 10), indicating no severe multicollinearity issues were evident among the independent variables. The Durbin-Watson statistics range from 1.040 to 1.250. Values close to 2 indicate no autocorrelation; values significantly below 2 suggest a positive autocorrelation. The findings show there is a potential positive autocorrelation in all sectors, but it is not extreme. Breusch-Pagan Test (Breusch and Pagan, 1979) for Heteroscedasticity shows that all sectors show significant values (*p*-values = 0.000), indicating the presence of heteroscedasticity. This means the variance of errors is not constant and depends on the values of the independent variables. Wooldridge Test for Autocorrelation in Panel Data indicates that most sectors show non-significant results, suggesting no autocorrelation (Wooldridge, 2010).

However, the Consumer sector has a *p*-value close to significance (*p* = 0.101), indicating a potential autocorrelation issue in this sector. Wald Test for heteroscedasticity in panel data shows that all sectors show significant values (*p*-values = 0.000), confirming the presence of heteroscedasticity in the panel data. Pesaran CD Test for Cross-Sectional Dependence shows no significant cross-sectional dependence across all sectors (*p*-values > 0.05). This implies that the residuals are not correlated across different cross-sections. Similar to the Pesaran CD test, the results strongly suggest there is no significant cross-correlation across sectors (p-values > 0.05). Phillips-Perron Test for Stationarity shows that the data is stationary across all sectors, with significant negative values revealing the absence of unit roots. In summary, the analysis finds that the tests consistently demonstrate the presence of heteroscedasticity and in some cases, autocorrelation, across all sectors. These issues need to be addressed to ensure the validity of the regression models used in the analysis.

Table A1. Fixed effects assumption tests.

Statistics Tests	Agro	Consump	Fincial	Indus.	Propcon	Resourc	Service	Tech
VIF	1.020–1.129	1.053–1.451	1.014–1.593	1.044–1.273	1.008–1.343	1.033–1.40	1.028–1.247	1.036–1.328
Durbin Watson	1.250	1.109	1.040	1.080	1.180	1.191	1.156	1.090
Breusch-Pagan test	56.489 (0.000)	79.019 (0.000)	209.949 (0.000)	107.241 (0.000)	377.435 (0.000)	144.836 (0.000)	290.009 (0.000)	63.688 (0.000)
Wooldridge test for autocorrelation in panel	0.356 (0.603)	2.806 (0.101)	1.537 (0.241)	0.024 (0.980)	0.5174 (0.425)	0.672 (0.441)	0.979 (0.722)	2.768 (0.131)
Wald test for heteroscedasticity in panel	13142.6 (0.000)	18457.4 (0.000)	10224.3 (0.000)	10152.6 (0.000)	22714 (0.000)	12108.4 (0.000)	35205.4 (0.000)	20040.3 (0.000)
Pesaran CD test for cross-sectional dependence	−0.902 (0.367)	−0.121 (0.903)	−1.029 (0.303)	−0.242 (0.808)	1.499 (0.133)	−1.103 (0.255)	−1.014 (0.310)	−0.460 (0.645)
Phillips Perron test Stationary	(−24.096–2.411)	(−18.763–5.211)	(−29.018–−4.410)	(−33.606–−9.201)	(−7.564–−34.261)	(−24.260–−6.251)	(−8.266–−31.761)	(−13.408–−5.164)
Interpret	A and H	A and H	A and H	A and H	A and H	A and H	A and H	A and H

Note: A = Autocorrelation, H = Heteroscedasticity.