Cogent Business & Management

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/oabm20

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To cite this article: Ibrahim Adam , Abednego Osei & Rita Akua Aboagye (2025) Firms and the path to circular economy: unveiling the impact of ownership dynamics and innovation capacity through advanced econometric and quantile regression analysis, Cogent Business & Management, 12:1, 2483369, DOI: 10.1080/23311975.2025.2483369

To link to this article: https://doi.org/10.1080/23311975.2025.2483369

Published online: 28 Mar 2025.

COGENT BUSINESS & MANAGEMENT
2025, VOL. 12, NO. 1, 2483369
https://doi.org/10.1080/23311975.2025.2483369

ACCOUNTING, CORPORATE GOVERNANCE & BUSINESS ETHICS | RESEARCH ARTICLE

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Firms and the path to circular economy: unveiling the impact of ownership dynamics and innovation capacity through advanced econometric and quantile regression analysis

Ibrahim Adam[a], Abednego Osei[b,c] and Rita Akua Aboagye[d]

[a]Department of Finance and Economics, Faculty of Business and Law, Manchester Metropolitan University, Manchester, United Kingdom; [b]School of Business, University of Liberia, Monrovia, Liberia; [c]School of Finance and Economics, Jiangsu University, Zhenjiang, China; [d]School of Management, Jiangsu University, Zhenjiang, China

ABSTRACT

In the face of escalating environmental challenges and growing economic pressures, the circular economy (CE) has emerged as a transformative pathway toward sustainable development. This study explores the impact of ownership dynamics on CE performance among manufacturing firms in the MENA region, with a particular focus on the moderating role of innovation capacity. Grounded in the Resource-Based View and Agency Theory, the analysis draws on panel data from 447 listed firms spanning 2010 to 2022. Using the GMM estimator and quantile regression analysis, the findings reveal significant heterogeneity in the effects of ownership types: family and foreign ownership are negatively associated with CE performance, while managerial, state, and institutional ownership show positive and significant relationships highlighting the importance of governance alignment, public resource leverage, and institutional influence. Innovation capacity emerges as a key enabler, enhancing the effectiveness of ownership dynamics by promoting advanced CE practices and operational efficiencies. Robustness checks, including heterogeneity and sensitivity analyses, confirm the consistency of the results across sectors and performance levels. The study offers actionable insights for policymakers and business leaders, recommending targeted strategies to align ownership structures, strengthen innovation ecosystems, and accelerate sustainability transitions in emerging markets.

ARTICLE HISTORY
Received 2 September 2024
Revised 10 March 2025
Accepted 18 March 2025

KEYWORDS
Circular economy performance; ownership dynamics; firm innovation capacity; advanced econometrics; quantile regression; sustainable development; emerging markets

SUBJECTS
Business, Management and Accounting; Industry & Industrial Studies; Sustainable Development

1. Introduction

In the modern business landscape, transitioning to a circular economy (CE) has emerged as a pivotal strategy for fostering sustainability and achieving resource efficiency. By redefining how value is created, CE emphasizes the importance of minimizing waste, extending the lifecycle of resources and integrating regenerative systems into business models (Alcalde-Calonge et al., 2024; Chen, 2023; Le et al., 2024). This shift is particularly vital in the Middle East and North Africa (MENA) region, where resource-intensive economies are grappling with the dual pressures of environmental degradation and economic transformation. For MENA firms, the adoption of CE principles presents an unparalleled opportunity to address these challenges while unlocking pathways to economic diversification and innovation. However, transitioning to CE requires more than incremental adjustments to existing practices; it necessitates a systemic overhaul of traditional production and consumption patterns (Esposito et al., 2024; Jabbour et al., 2020).

CONTACT Abednego Osei oseidegraftabednego@gmail.com School of Business, University of Liberia, Monrovia, Liberia

Firms in the MENA region face unique structural and contextual barriers to CE adoption, which vary widely across industries and national contexts. Among these challenges, the ownership dynamics of firms emerges as a critical yet underexplored determinant of CE performance. Ownership dynamics—whether state-owned, privately held or a hybrid of both—shapes the strategic priorities of firms, their capacity to mobilize resources, and their responsiveness to sustainability imperatives (Esposito et al., 2023; Palea et al., 2024). For instance, state-owned enterprises (SOEs), which dominate key sectors like energy and manufacturing, often possess the financial resources and political backing to drive large-scale CE initiatives. However, they are frequently hindered by bureaucratic inefficiencies and short-term political agendas that misalign with sustainability goals (Baah et al., 2024; Minoja & Romano, 2024). On the other hand, privately held firms, while often more agile and innovative, may lack the scale or long-term investment capacity required to implement transformative CE practices. Mixed-ownership models, which combine public accountability with private-sector efficiency, introduce yet another layer of complexity, offering both opportunities and challenges (Opferkuch et al., 2021; Osei et al., 2025). Understanding the influence of these ownership dynamics is essential to unlocking the MENA region's potential for CE leadership.

While ownership dynamics lays the foundation for a firm's CE strategy, it is not sufficient to ensure successful adoption. Innovation capacity emerges as a critical enabler, amplifying a firm's ability to implement and scale CE practices effectively. Innovation empowers firms to redesign value chains, integrate advanced technologies and develop sustainable business models that align profitability with ecological goals (Esposito et al., 2023). For example, firms with robust innovation capacity can create products designed for durability and recyclability, deploy renewable energy systems, and implement smart waste management solutions (L'Abate et al., 2024; Suchek et al., 2021). Furthermore, innovation allows firms to navigate regulatory and market uncertainties, issues that are particularly relevant in the MENA region, where supportive CE policies are still in their infancy.

Despite the transformative potential of the CE, its adoption in the MENA region remains fragmented and inconsistent, hindered by structural, contextual and organizational challenges. Among these, the relationship between ownership dynamics and CE performance remains critically underexplored. While existing studies have primarily examined ownership structures in relation to financial performance or innovation capacity as an independent factor, research on their combined influence on CE performance is limited (Amin et al., 2024; Boshnak, 2024; Jabbouri et al., 2023; Wen et al., 2023). Additionally, most research focuses on financial and operational outcomes, neglecting CE-specific metrics such as resource efficiency, waste reduction and lifecycle management (Enciso-Alfaro & García-Sánchez, 2024; Le et al., 2024). Other studies broadly examine governance structures but fail to consider the unique complexities of ownership models—state-owned, private or mixed—and their direct impact on CE adoption (Esposito et al., 2023; Minoja & Romano, 2024; Opferkuch et al., 2021; Palea et al., 2024). These gaps highlight the need for a deeper investigation into how ownership dynamics shaped strategic priorities, resource allocation, and sustainability transitions, particularly in emerging markets like MENA.

Additionally, innovation capacity—a critical enabler of CE adoption—has not been adequately explored as a moderating factor in the ownership-CE relationship. While innovation enables firms to redesign value chains, adopt advanced technologies, and overcome systemic barriers, its role in mitigating constraints or enhancing opportunities presented by different ownership dynamics remains unclear (Mishra et al., 2024; Suchek et al., 2021; Ul-Durar et al., 2023). For instance, innovation could allow state-owned enterprises (SOEs) to navigate bureaucratic inefficiencies or help private firms scale sustainability practices despite limited resources. However, empirical studies rarely address these interactions, particularly in the distinct socio-economic and institutional landscape of the MENA region.

To comprehensively examine the impact of ownership structures and firm innovation capacity on CE performance, this study employs the generalized method of moments (GMM), quantile regression and sectoral heterogeneity analysis to provide a more detailed and nuanced understanding of how these relationships vary across firms and industries. Quantile regression is particularly valuable as it enables the estimation of ownership effects across different levels of CE performance, rather than relying on mean estimates alone. By doing so, the study reveals whether ownership dynamics exert a stronger influence on firms with high CE performance or whether challenges in CE adoption are more pronounced among lower-performing firms. This approach helps identify whether ownership structures disproportionately

benefit firms that are already sustainability leaders or whether they play a more critical role in supporting firms struggling to adopt CE practices.

Moreover, sectoral heterogeneity analysis is employed to assess variations across industries, acknowledging that firms in different sectors face unique regulatory, technological and market-driven constraints. The MENA region's industrial landscape is highly diverse, with some sectors—such as manufacturing and energy—having higher resource dependencies and environmental footprints than others. By incorporating sectoral analysis, the study examines whether ownership effects are uniform across industries or if industry-specific factors mediate the ownership-CE relationship.

Building on these methodological insights, this study seeks to address the broader gaps in literature by formulating key research questions that explore the intersection of ownership dynamics, innovation capacity, and CE adoption in the MENA region. Specifically, it aims to answer: (1) How do ownership dynamics directly influence the CE performance of firms in the MENA region? (2) To what extent does firm innovation capacity moderate the relationship between ownership dynamics and CE performance? (3) How do the unique socio-economic and institutional conditions of the MENA region influence the interaction between ownership structure, innovation capacity and CE performance? (4) How do ownership effects on CE performance vary across different levels of CE adoption, and what sectoral differences influence these relationships? By integrating these research dimensions, the study provides a comprehensive framework that captures both firm-level and industry-specific variations, offering new theoretical insights and practical implications for sustainability transitions in emerging markets.

This study provides significant contributions to literature and policy in several ways. First, this study is among the first to examine the direct relationship between ownership dynamics and CE performance in the MENA region. Unlike previous studies that primarily focus on financial and operational metrics, this research emphasizes environmental outcomes and CE-specific metrics such as resource efficiency, waste reduction, and lifecycle management. By addressing the unique governance complexities of state-owned, private and mixed-ownership models in the MENA context, the study contributes novel insights tailored to resource-intensive and institutionally fragmented economies.

Second, the study breaks new ground by investigating firm innovation capacity as a moderating variable in the ownership-CE relationship. While innovation is widely recognized as a driver of CE, its interaction with governance models to overcome systemic barriers and scale CE practices has been largely neglected. This research highlights how innovation can mitigate governance inefficiencies in SOEs, enhance scalability for private firms, and resolve conflicts in mixed-ownership models, offering actionable insights for firms with varying ownership dynamics.

Third, the study provides a novel contribution by employing quantile regression and sectoral heterogeneity analysis to examine variations in ownership effects across different levels of CE adoption and industry contexts. While previous studies generally assess average ownership effects, this research provides a granular analysis, revealing whether ownership structures exert stronger effects on highly sustainable firms or are more impactful for those lagging in CE adoption. Furthermore, by examining sectoral heterogeneity, the study identifies whether industry-specific factors, such as regulatory pressures, resource dependencies and technological advancements, shape the ownership-CE relationship differently across sectors. This approach enhances the applicability of findings by offering sector-specific policy recommendations and firm-level strategies tailored to diverse industrial settings in the MENA region.

Fourth, the study integrates resource-based view (RBV) and agency theory with CE research to develop a comprehensive framework that explains how ownership dynamics and innovation capacity jointly influence CE performance. While existing research predominantly relies on stakeholder theory, this study highlights the internal governance and resource mobilization dynamics crucial for sustainability transitions. By bridging these theoretical perspectives, the research provides a more nuanced understanding of the mechanisms enabling or constraining CE adoption.

Finally, the findings of this study offer actionable recommendations for aligning governance and innovation strategies with sustainability goals. Policymakers can leverage these insights to design targeted interventions and incentives that encourage CE adoption across different ownership models. Business leaders can use the framework to optimize resource allocation, enhance innovation capabilities and align corporate governance structures with environmental and economic objectives.

The study proceeds with the literature review, methods, empirical analysis and discussions and finally, conclusion and policy implications.

2. Literature review

This section shows the theoretical underpinning, empirical evidence and hypothesis development.

2.1. Theoretical underpinning

2.1.1. Resource-based view (RBV) theory

The resource-based view (RBV) provides a vital theoretical lens for understanding how firms achieve competitive advantage by leveraging unique internal resources and capabilities (Barney, 1991). RBV posits that firms with Valuable, Rare, Inimitable, and Non-substitutable (VRIN) resources can sustain a competitive advantage (Liguori, Lee, et al., 2024). In the context of CE adoption, VRIN resources play a pivotal role in promoting resource efficiency, waste reduction and lifecycle management. For instance, proprietary technologies, R&D capabilities and organizational expertise in recycling and sustainable production represent VRIN resources that firms can leverage to advance CE initiatives. This study employs RBV to analyze the critical role of ownership dynamics in shaping the accessibility, allocation, and utilization of these resources, emphasizing how state-owned, private and mixed-ownership firms differ in their ability to achieve CE outcomes.

Ownership dynamics directly influence a firm's resource configuration and strategic decision-making (Esposito et al., 2023; Minoja & Romano, 2024). For example, state-owned enterprises (SOEs) in the MENA region benefit from significant financial backing and political support, enabling them to initiate large-scale sustainability projects. However, these firms often struggle with bureaucratic inefficiencies, rigid structures, and misaligned priorities, leading to suboptimal resource utilization, as suggested by RBV. A real-world example is Masdar, a UAE-based SOE specializing in renewable energy. Despite access to substantial financial and policy support, regulatory complexities have slowed the implementation of several CE initiatives. In contrast, privately held firms demonstrate greater agility and market responsiveness, allowing them to quickly implement innovative CE solutions (Jabbour et al., 2020). For example, the Egyptian textile industry has seen private firms develop closed-loop recycling practices, which have successfully reduced waste.

Innovation capacity is a key enabler within the RBV framework, as it enhances a firm's ability to develop and apply advanced technologies for CE implementation (Kristoffersen et al., 2021; Wen et al., 2023). Firms with strong innovation capabilities can reconfigure value chains, design recyclable products, and integrate renewable energy solutions (Chen et al., 2024; Liguori, Muldoon, et al., 2024). A compelling regional example is the UAE's smart waste management initiative, where technology-driven private firms have developed AI-powered recycling solutions to optimize resource utilization. These technological innovations allow firms to overcome resource constraints, enabling SOEs to mitigate bureaucratic inefficiencies while allowing private firms to scale CE solutions despite limited capital access. This study refines the understanding of how ownership dynamics interact with innovation capacity to drive CE adoption in resource-dependent and institutionally fragmented economies such as the MENA region. While RBV underscores the importance of innovation as a strategic resource, this study goes further by illustrating how different ownership structures either facilitate or hinder the translation of innovation capacity into CE outcomes.

Beyond its traditional application in understanding competitive advantage, this study extends RBV's role as a governance mechanism that influences strategic resource alignment in sustainability transitions. While prior RBV research has extensively explored how firms achieve competitive advantages through resource accumulation, this study uniquely highlights how different ownership structures impact the operationalization of VRIN resources in CE adoption. For example, previous studies have emphasized the inefficiencies of SOEs, but this research substantiates these claims with empirical insights from the MENA region (Bocken & Geradts, 2020; Esposito et al., 2023; Minoja & Romano, 2024). Similarly, while private firms are often described as more agile, this study strengthens the argument by demonstrating how specific market-driven challenges shape their CE strategies (Agyemang et al., 2023).

2.1.2. Agency theory

Agency theory provides a critical framework for understanding the governance dynamics and principal-agent relationships within firms, making it highly relevant to the study of ownership structures and CE adoption. The theory highlights how misaligned incentives, information asymmetry, and conflicts of interest between principals (owners) and agents (managers) can hinder strategic decision-making and resource allocation (Jensen & Meckling, 2019). These governance challenges become particularly pronounced in CE adoption because sustainability initiatives often require long-term investments, multi-stakeholder coordination, and a shift from traditional profit-driven strategies. Unlike conventional business projects that generate relatively immediate financial returns, CE adoption demands high upfront investments with delayed return on investment (ROI), making it more susceptible to agency-related conflicts.

State-owned enterprises (SOEs) in the MENA region provide a compelling application of agency theory. As government-controlled entities, SOEs often operate with dual and sometimes conflicting objectives: achieving political or social goals while maintaining operational efficiency (Agyemang et al., 2023; Esposito et al., 2024). This duality often results in misaligned incentives, where managers prioritize political agendas or employment stability over sustainability-driven initiatives such as CE. A key reason for weak accountability mechanisms in SOEs is that these firms are less subject to direct market pressures, allowing managers to operate with reduced oversight and limited consequences for inefficiencies (Agyemang et al., 2020; Saeed et al., 2024). Without clear incentives to pursue sustainability, SOE-led CE projects can suffer from underinvestment in green technologies, slow adoption of circular strategies, or inefficiencies in implementation, even when financial and technical resources are available. A real-world example is the delayed execution of large-scale CE projects in North Africa, where government-led waste-to-energy initiatives faced prolonged bureaucratic hurdles due to shifting policies and lack of effective monitoring.

Conversely, privately held firms tend to have more direct principal-agent relationships, resulting in closer alignment between owners and managers (Esposito et al., 2023; Kristoffersen et al., 2021). This alignment facilitates faster decision-making, greater flexibility, and a stronger focus on profitability and innovation, allowing these firms to adopt CE strategies more efficiently. However, a key limitation of private firms is their focus on short-term financial goals, which often conflict with the long-term investment nature of CE adoption. Many CE initiatives require substantial upfront capital expenditure in areas such as waste management infrastructure, sustainable supply chains, and renewable energy solutions, but the financial benefits may not materialize for years. In industries with tight profit margins, firms may hesitate to allocate resources to CE efforts unless supported by policy incentives, regulatory frameworks or external funding mechanisms. For example, privately-owned manufacturers in the MENA region have struggled to integrate CE principles due to the lack of immediate cost savings, despite the long-term environmental and economic benefits (Boshnak, 2024; Jabbouri et al., 2023).

Innovation capacity serves as a critical mitigating factor in overcoming agency-related challenges across all ownership models. By leveraging digital tools such as blockchain-based transparency systems and AI-driven monitoring, firms can enhance accountability, reduce information asymmetry, and ensure compliance with sustainability commitments (Enciso-Alfaro & García-Sánchez, 2024). Innovation also plays a key role in making CE adoption more financially attractive by lowering implementation costs and improving operational efficiencies, addressing one of the primary concerns of profit-driven private firms. Additionally, R&D investments in sustainable production technologies and closed-loop systems can help SOEs and mixed-ownership enterprises align sustainability efforts with economic goals, reducing governance friction. Integrating innovation earlier in CE planning ensures that firms do not perceive sustainability initiatives as separate from financial strategy, but rather as a value-adding competitive advantage.

2.2. Empirical evidence and hypotheses development

This section explores how various ownership structures impact CE performance, using insights from RBV and Agency Theory. It provides a foundation for developing hypotheses on the role of family, foreign, managerial, state, and institutional ownership in shaping firms' sustainability strategies.

2.2.1. Family ownership (FO) and CE performance

Family ownership (FO) is a governance structure characterized by concentrated ownership and decision-making closely tied to familial interests, which significantly influences a firm's approach to CE performance. Drawing on agency theory, family-owned firms typically experience lower principal-agent conflicts, as family members often serve as both owners and managers (L'Abate et al., 2024). This alignment reduces monitoring costs and facilitates quicker, cohesive decision-making, allowing family firms to prioritize long-term goals over short-term profits (Chang, Wiredu, et al., 2024). Such a focus is conducive to CE adoption, which requires strategic investments in sustainability practices like resource efficiency, waste reduction and lifecycle management. From the perspective of the resource-based view, family ownership contributes unique resources such as trust, community ties, and reputational capital, which can enhance the firm's ability to implement CE practices. For example, family firms often value intergenerational sustainability, aligning their business strategies with CE objectives to preserve resources and maintain their legacy. However, family ownership can also impose constraints (Esposito et al., 2024). Family firms are often risk-averse, which may limit their willingness to invest in innovative, high-risk CE practices or collaborate with external stakeholders, both of which are critical for achieving transformative sustainability goals. Empirical studies present mixed findings (Esposito et al., 2023; Palea et al., 2024), with some highlighting family firms' commitment to environmental goals and others noting their reluctance to embrace innovation high investment in sustainability (Opferkuch et al., 2021; Wen et al., 2023). In the MENA region, where family ownership dominates resource-intensive sectors, strong local ties and community-oriented reputations position these firms to align with CE principles, despite challenges from fragmented regulations and limited access to green technologies. Accordingly, we hypothesize:

H1: *Family ownership is positively associated with CE performance.*

2.2.2. Foreign ownership (FRO) and CE performance

Foreign ownership (FRO) provides firms with critical resources such as financial capital, advanced technologies and international best practices, enhancing their ability to adopt CE practices (Jabbour et al., 2020). Drawing on the RBV, foreign investors often enforce global sustainability standards and encourage firms to integrate CE principles—such as resource efficiency, waste reduction, and lifecycle management—to meet international regulatory and market expectations. These resources foster innovation, operational efficiency, and knowledge spillovers, strengthening CE performance. However, while RBV highlights the benefits of resource acquisition, governance complexities introduced by agency conflicts must also be considered. As explained by agency theory, foreign investors, acting as principals, impose strict performance monitoring and governance mechanisms to align firms with sustainability objectives (Zhu, Yang, et al., 2024). While these external pressures incentivize CE adoption, they may also create governance conflicts due to differences in managerial priorities, risk tolerance and cultural expectations between foreign and local stakeholders (Esposito et al., 2024; L'Abate et al., 2024). Misalignment in strategic objectives, particularly in markets with weak legal enforcement and regulatory uncertainty, can delay CE implementation or reduce its effectiveness.

Although foreign ownership can accelerate CE adoption through technology transfer, managerial expertise and compliance enforcement, institutional barriers can moderate its impact. In emerging markets, regulatory inconsistencies, cultural resistance, and weak institutional frameworks can hinder the execution of foreign-driven CE strategies, leading to inefficiencies and operational delays. Empirical research suggests that foreign-owned firms generally outperform domestic firms in sustainability metrics due to greater exposure to international markets and investor-driven pressures (Enciso-Alfaro & García-Sánchez, 2024; Esposito et al., 2023; Minoja & Romano, 2024). For example, Morocco's renewable energy sector has leveraged European investment partnerships to develop solar power projects aligned with CE principles, while foreign-backed Egyptian manufacturing firms have integrated circular production models through technology transfer and global compliance incentives (Boshnak, 2024; Jabbouri et al., 2023). However, in some MENA countries, foreign investors have struggled with unclear CE regulations and local resistance, limiting long-term sustainability outcomes. While foreign ownership positively influences CE performance, its success is contingent on strong governance alignment, regulatory

clarity and the ability to integrate sustainability goals into local business environments. Based on these insights, we propose the following hypothesis:

H2: *Foreign ownership is positively associated with CE performance.*

2.2.3. Managerial ownership (MO) and CE performance

Managerial ownership (MO), where managers hold a significant ownership stake in the firm, aligns the interests of owners and managers, creating a direct incentive for managers to make decisions that enhance firm value and long-term sustainability (Osei, Zhu, Borgi, et al., 2025). Drawing on agency theory, MO reduces principal-agent conflicts by aligning the goals of managers (agents) with those of shareholders (principals) (Minoja & Romano, 2024; Wen et al., 2023). This alignment is particularly relevant for CE adoption, as it requires strategic investments in sustainability initiatives, resource efficiency, and waste reduction. From the perspective of the resource-based view, managerial ownership fosters a unique form of resource mobilization by leveraging the knowledge, decision-making autonomy and commitment of managers to drive CE performance (Liguori, Muldoon, et al., 2024). Managerial ownership empowers managers to implement innovative CE practices such as lifecycle management, renewable energy integration and circular product design, as they have a vested interest in ensuring the firm's sustainability success. Empirical evidence indicates that firms with higher managerial ownership are more likely to adopt proactive environmental practices, as managers with ownership stakes are motivated to mitigate risks and enhance the firm's long-term value (Amin et al., 2024; L'Abate et al., 2024; Opferkuch et al., 2021). In the MENA region, where firms often operate in resource-intensive industries and face fragmented regulatory frameworks, MO offers an opportunity to enhance CE performance by fostering managerial accountability and innovation. Based on these insights, we propose the following hypothesis:

H3: *Managerial ownership is positively associated with CE performance.*

2.2.4. State ownership (so) and CE performance

State ownership (SO), where a significant portion of a firm's equity is controlled by government entities or state-owned enterprises (SOEs), plays a unique role in influencing CE performance. Drawing on agency theory, state-owned enterprises often experience challenges related to bureaucratic inefficiencies and misaligned incentives (Esposito et al., 2023; Wiredu et al., 2023). These governance issues can hinder their ability to implement transformative CE practices, particularly when short-term political objectives conflict with long-term sustainability goals. However, the principal-agent relationship in state-owned firms may also offer advantages, as government ownership can prioritize social and environmental objectives that align with CE principles, even at the expense of immediate profitability. From the perspective of the resource-based view, state-owned firms possess distinct advantages, including access to substantial financial resources and political support, which can facilitate large-scale investments in CE initiatives (Esposito et al., 2024; Le et al., 2024). Empirical evidence found that state-owned firms often lead large-scale environmental projects due to their access to resources and policy backing (Esposito et al., 2023; Minoja & Romano, 2024; Palea et al., 2024). In the MENA region, where state ownership is prevalent in resource-intensive industries such as energy, manufacturing and transportation, these dynamics are particularly relevant. Based on these insights, we propose the following hypothesis:

H4: *State ownership is positively associated with CE performance.*

2.2.5. Institutional ownership (IO) and CE performance

Institutional ownership (IO), where large financial institutions such as pension funds, mutual funds and insurance companies hold significant equity stakes in a firm, plays a pivotal role in shaping strategic priorities, including CE adoption. Institutional investors often act as sophisticated stakeholders with the ability and influence to demand higher environmental performance and long-term value creation (Amin et al., 2024; L'Abate et al., 2024). Drawing on agency theory, institutional ownership reduces principal-agent conflicts by imposing strong governance and oversight mechanisms (Liguori, Muldoon, et al., 2024). Institutional investors frequently advocate for sustainable business practices, encouraging firms to adopt CE principles such as resource efficiency, waste reduction, and lifecycle management

to align with their ESG mandates. From the perspective of the resource-based view, institutional ownership introduces access to critical financial and strategic resources, including capital for sustainability investments and expertise in managing environmental risks (Chen, 2023; Cramer, 2020). Institutional investors often bring global best practices and advanced knowledge of sustainability trends, which can drive innovation and efficiency in CE adoption. Empirical evidence shown that institutional investors often push for improved environmental performance, holding firms accountable for meeting international sustainability standards and reducing their environmental footprints (Esposito et al., 2023; L'Abate et al., 2024; Minoja & Romano, 2024). In the MENA region, institutional ownership is emerging as a significant governance mechanism, particularly in sectors such as energy, manufacturing and finance, where CE adoption is gaining traction. Based on these insights, we propose the following hypothesis:

H5: *Institutional ownership is positively associated with CE performance.*

2.2.6. The moderating effects of firm innovation capacity

Innovation capacity plays a crucial moderating role in the relationship between ownership structures and CE adoption by enhancing resource utilization, governance efficiency and risk mitigation. From an RBV perspective, innovation capacity acts as a valuable and inimitable resource, enabling firms to overcome systemic barriers in CE adoption through advanced technologies, circular business models, and smart waste management solutions (Mishra et al., 2024; Ul-Durar et al., 2023). However, beyond RBV, innovation also mitigates agency conflicts by reducing information asymmetry and aligning managerial incentives with long-term sustainability goals (Liguori, Lee, et al., 2024). High innovation capacity enables firms to justify CE investments by demonstrating financial viability, operational efficiencies, and strategic advantages, making it easier for owners and managers to align on sustainability objectives. The moderating effect of innovation varies across ownership structures—family-owned firms can overcome resource constraints and risk aversion, foreign-owned firms can adapt global technologies to local regulatory contexts, and institutional ownership can leverage innovation to meet investor-driven environmental requirements (Kristoffersen et al., 2021; Le et al., 2024). Managerial ownership, where managers also hold equity stakes, benefits from innovation-driven CE strategies that maximize both financial returns and sustainability impacts.

Empirical evidence suggests that firms with greater innovation capacity are more successful in CE adoption, as they develop circular production models, improve operational efficiencies and navigate regulatory complexities more effectively (Hojnik et al., 2023; Khan et al., 2024; Suchek et al., 2021). In the MENA region, where regulatory fragmentation and reliance on resource-intensive industries pose significant sustainability challenges, innovation has proven to be a critical enabler of CE strategies. For example, renewable energy firms in the UAE have integrated solar and waste-to-energy technologies, overcoming infrastructure and policy hurdles, while textile manufacturers in Egypt have implemented closed-loop recycling systems to reduce raw material dependency (Boshnak, 2024; Jabbouri et al., 2023). These examples highlight that innovation capacity enhances firms' ability to align ownership structures with CE objectives, lower implementation costs and ensure long-term compliance with sustainability standards. Thus, we propose the following hypothesis:

H6: *Firm innovation capacity positively moderates the relationship between ownership dynamics and CE performance.*

3. Methods

This section shows the methodologies employed in the study.

3.1. Sampling and data sources

The MENA region offers a unique context for studying CE adoption due to its resource-intensive economies, significant environmental challenges and diverse ownership structures (Khan et al., 2020). The region faces increasing pressure to address sustainability goals, as reflected in Saudi Arabia's Vision 2030

and the UAE's CE Policy (Tahir et al., 2022). However, fragmented regulatory frameworks and limited access to innovation create barriers to CE implementation. Given its diverse governance models—state-owned, family-owned, foreign, managerial and institutional ownership—understanding how these ownership types influence CE adoption is essential. State-owned enterprises (SOEs) often benefit from financial and political support, enabling large-scale sustainability projects but may suffer from bureaucratic inefficiencies and slow decision-making. Family-owned firms, which prioritize long-term business stability, tend to adopt CE gradually, yet their risk aversion and limited external capital access can hinder large-scale investments. Foreign-owned firms, driven by global sustainability standards, frequently introduce advanced CE technologies and enforce international environmental practices, though they may encounter institutional and regulatory misalignment in the MENA region. Managerial ownership, where managers have a financial stake in the firm, aligns CE initiatives with performance-based incentives, promoting more flexible and strategic CE integration. Lastly, institutional ownership exerts external pressure for sustainability disclosure and regulatory compliance, encouraging firms to adopt transparent and measurable CE initiatives. By examining how these governance structures influence CE implementation in manufacturing firms, this study provides valuable insights into sustainability transitions in resource-dependent and institutionally complex contexts.

This study employs a quantitative research design to examine the impact of ownership structures and innovation capacity on CE performance. The focus on listed manufacturing firms is justified by their strong regulatory compliance, structured governance and availability of standardized sustainability data, making them more suitable for cross-firm comparisons. While SMEs also contribute to CE adoption, listed firms provide greater data availability and consistency, allowing for a robust large-scale trend analysis. The sample consists of 447 listed manufacturing companies in the MENA region from 2010 to 2022, a period selected to capture major policy shifts and sustainability transitions. This timeframe encompasses the emergence of CE frameworks such as Saudi Arabia's Vision 2030, the UAE's CE Policy and global agreements like the Paris Agreement in 2015. It also reflects key economic transformations, including diversification from oil dependency and advancements in green technology and innovation (Khan et al., 2020; Tahir et al., 2022). By leveraging a consistent dataset from 2010 to 2022, this study ensures comparability across firms and enables a meaningful trend analysis of CE adoption in response to evolving regulatory, economic and technological landscapes.

Corporate governance data, including ownership dynamics and firm-level data, were sourced from the Thomson Reuters Eikon Database, while macroeconomic variables, including economic growth and foreign direct investment, were obtained from the World Development Indicators (WDI) Database . CE performance data were obtained from sustainability reports, which provide firm-level disclosures on sustainability efforts, resource efficiency and environmental impact. While differences in reporting standards may pose reliability concerns, sustainability reports remain one of the most widely used and credible sources for tracking corporate CE performance.

3.2. Measurement of variables

This section outlines the methodology for measuring key variables in the study. It details the assessment framework for CE performance and explains how different ownership structures, innovation capacity, and control variables are quantified to ensure a robust and reliable analysis.

3.2.1. Circular economy performance

The dependent variable, CE Performance, is measured using a categorized framework that evaluates a firm's adoption of CE practices across multiple dimensions. This framework aligns with established guidelines, such as the Global Reporting Initiative (GRI), Sustainable Development Goal (SDG) 12 and International Organization for Standardization (ISO) standards, ensuring a robust and standardized approach. It comprises 31 validated items sourced from the literature and nine additional indicators developed by the authors, resulting in a total of 40 CE indicators. These indicators are categorized into key dimensions, including resource efficiency and productivity, circular design and innovation, circular supply chain management, waste management and recycling, business model transformation, emissions

and environmental impact, financial performance linked to CE, stakeholder engagement and collaboration, social impacts of CE, governance and policy alignment and digital tools and technology use. The evaluation of these indicators and their categorization is detailed in Table 1, which provides a comprehensive breakdown of the CE Index used in this study.

To ensure the reliability and validity of the indicators, a rigorous scale refinement process was undertaken. Initially, a comprehensive pool of indicators was derived from an extensive literature review and established reporting guidelines (GRI, SDG 12, ISO). The content validity of these indicators was assessed by consulting sustainability experts and industry practitioners to confirm their relevance to CE performance. A pilot study was conducted using a sample of 50 sustainability reports to test the clarity and applicability of each indicator. Based on the results, ambiguous or redundant items were refined or eliminated, resulting in a concise yet comprehensive framework of 40 indicators, capturing critical dimensions of CE practices (Table 1).

Each indicator was carefully designed to capture specific aspects of CE adoption, with the scoring system standardized on a 0–3 scale to ensure consistent evaluation across firms (Esposito et al., 2023; Minoja & Romano, 2024; Opferkuch et al., 2021; Osei, Zhu, Borgi, et al., 2025; Palea et al., 2024). A score of 0 was assigned for no implementation or disclosure, 1 for minimal or qualitative information, 2 for detailed quantitative evidence and 3 for comprehensive reporting, including quantitative metrics and measurable achievements aligned with sustainability goals. The total CE score for each firm was calculated using an unweighted method, dividing the firm's actual score by the total possible score, as presented in Table 1. This systematic approach ensured that the scoring framework reflected the depth and quality of CE practices disclosed in sustainability reports.

Table 1. Evaluation of CE index.

Categories	Items	References
Resource efficiency and productivity	Material productivity	(Jabbour et al., 2020)
	Energy efficiency	(Minoja & Romano, 2024)
	Water use intensity	(Chen, 2023)
	Waste reduction	(Kristoffersen et al., 2021)
Circular design and innovation	Renewable materials	(Esposito et al., 2024)
	Modular design	Authors Elaborations
	End-of-life recovery systems	(L'Abate et al., 2024)
	Recyclability	(Baah et al., 2024)
	Durability enhancements	(Chen, 2023)
Circular supply chain management	Closed-loop supply chains	(Minoja & Romano, 2024)
	Use of secondary raw materials	(Palea et al., 2024)
	Traceability systems	Authors Elaborations
	Integration of reverse logistics	(Le et al., 2024)
Waste management and recycling	Waste diversion rates	(Enciso-Alfaro & García-Sánchez, 2024)
	Proportion of waste reused/recycled	(Ul-Durar et al., 2023)
	Recovery system efficiency	Authors Elaborations
	Hazardous waste reduction	(Khan et al., 2024)
Business model transformation	Adoption of leasing models	(Enciso-Alfaro & García-Sánchez, 2024)
	Product-as-a-service approaches	(Kristoffersen et al., 2021)
	Sharing economy initiatives	Authors Elaborations
	Circularity in service offerings	(Khan et al., 2024)
Emissions and environmental impact	Life cycle impact assessments	(Esposito et al., 2023)
	Adoption of renewable energy sources	(Jabbour et al., 2020)
Financial performance linked to CE	Cost savings from resource efficiency	(L'Abate et al., 2024)
	Revenue from recycled products	(Chen, 2023)
	Returns on CE investments	(Baah et al., 2024)
Stakeholder engagement and collaboration	Partnerships for CE innovation	Authors Elaborations
	Consumer take-back programs	(Esposito et al., 2024)
	Supplier collaboration	(Le et al., 2024)
Social impacts of CE governance and policy alignment	Training programs on CE practices	(Minoja & Romano, 2024)
	Compliance with CE regulations	(Palea et al., 2024)
	Participation in certification programs	(Kristoffersen et al., 2021)
	Engagement in industry-specific CE pacts	(Alcalde-Calonge et al., 2024)
Digital tools and technology use	Blockchain for material traceability	Authors Elaborations
	AI for resource optimization	Authors Elaborations
	IoT for monitoring resource flows	(Esposito et al., 2023)
	Smart monitoring of energy use	Authors Elaborations
Circular metrics at the macro level	Circular material uses rates	(Jabbour et al., 2020)
	Industrial symbiosis participation	(Esposito et al., 2024)
	Waste-to-energy projects	Authors Elaborations

To further confirm the reliability and validity of the measurement framework, inter-rater reliability was tested by having two independent coders assess a subsample of sustainability reports. The inter-rater agreement exceeded 90%, demonstrating high consistency in the scoring process. Additionally, exploratory factor analysis was conducted to verify the dimensionality of the indicators, ensuring that the constructs adequately captured the intended dimensions of CE performance. These rigorous testing and refinement processes establish a robust foundation for assessing CE practices, providing critical insights into firms' sustainability performance across diverse dimensions. The final CE index evaluation is detailed in Table 1, offering a structured representation of the assessment criteria.

$$CE\ \frac{\text{Actual disclosure scores}}{\text{Total scores disclosed}} \tag{1}$$

3.2.2. Ownership dynamics

Ownership dynamics, as the key independent variable, is measured using distinct indicators for different ownership types. Family ownership is measured as the percentage of shares held by family members or entities closely associated with the family (Amin et al., 2024). Foreign ownership is assessed based on the percentage of equity held by foreign individuals, institutions or entities (Boshnak, 2024). Managerial ownership is measured as the proportion of shares owned by the firm's executives, directors or other key decision-makers (Zhu, Osei, et al., 2024). Institutional ownership is quantified as the percentage of shares held by institutional investors, such as pension funds, mutual funds or insurance companies (Zhu, Osei, et al., 2024). State ownership is measured as the percentage of shares owned or controlled by government entities or state-owned enterprises (Wen et al., 2023). These measurements provide a clear and quantifiable representation of each ownership type, enabling a robust analysis of their respective impacts on CE performance.

3.2.3. Firm innovation capacity

Firm innovation capacity is measured using total expenditure on research and development (R&D) as a percentage of revenue. This metric captures the firm's financial commitment to fostering innovation and reflects its prioritization of developing new products, processes and technologies. A higher R&D-to-revenue ratio indicates a strong focus on innovation, as it demonstrates the firm's willingness to allocate substantial resources toward activities that enhance its competitive advantage and adaptability in dynamic markets. This measure is widely used in empirical research and offers a standardized approach for comparing innovation capacity across firms and industries (Hojnik et al., 2024; Khan et al., 2024; Mishra et al., 2024; Suchek et al., 2021). By focusing on R&D expenditure relative to revenue, the metric provides insight into how efficiently a firm leverages its resources to drive innovation and sustain long-term growth.

3.2.4. Control variables

To ensure robustness and accuracy in the analysis, the study incorporates a set of firm-level and national-level control variables that are critical in influencing CE performance. At the firm level, profitability is included as it reflects a firm's financial health and ability to invest in CE practices (Palea et al., 2024). Firm size is controlled to account for differences in resource availability and scalability, as larger firms may have greater capacity for implementing CE initiatives (Cobbinah et al., 2025; Esposito et al., 2023). Leverage, representing the ratio of debt to equity, is considered to capture the impact of a firm's financial structure on its ability to pursue sustainability goals (Osei et al., 2023; Wiredu et al., 2023).

Economic growth and foreign direct investment (FDI) are key macroeconomic factors influencing CE adoption in manufacturing firms. Higher economic growth fosters a favorable business environment, enabling firms to invest in CE initiatives by providing financial stability, increased demand for sustainable products and stronger regulatory support (Osei, 2024; Zhou, Osei, et al., 2024). However, during economic downturns, firms may prioritize short-term financial performance, delaying CE adoption. Meanwhile, FDI facilitates CE implementation by introducing international resources, advanced technologies and managerial expertise (Zhou, Osei, et al., 2024). Foreign investors promote technology transfer, knowledge

spillovers, and compliance with global environmental standards, accelerating circular production, waste reduction, and sustainable sourcing (Agyemang et al., 2020). Additionally, FDI imposes external sustainability requirements, aligning firms with international regulations and global market expectations. These controls help isolate the effects of ownership dynamics and innovation capacity while minimizing potential biases in the results.

3.3. Model construction

The study adopts a dynamic panel data model, building on the framework proposed by Esposito et al. (2023b), to examine the impact of ownership dynamics on CE performance. Log transformation is applied to firm size, leverage, economic growth, and FDI to reduce skewness, stabilize variance, and enhance regression accuracy, while ownership structures, innovation capacity, profitability and CE performance remain unlogged as they are already standardized or expressed as percentages. This selective approach ensures normality, improves interpretability and strengthens statistical inferences on ownership dynamics, innovation capacity and CE performance. The baseline model is as follows:

$$CE_{it} = \beta_0 + \beta_1 FO_{it} + \beta_2 FRO_{it} + \beta_3 MO_{it} + \beta_4 SO_{it} + \beta_5 IO_{it} + \beta_G \sum_{i=1}^{5} \gamma_i Controls_{it} + year + industry + \varepsilon_{it} \quad (2)$$

Where: CE_{it} is the CE performance of firm i at time t, FO_{it}, FRO_{it}, MO_{it}, SO_{it}, IO_{it}, represent the different ownership types (e.g. family, foreign, managerial, state and institutional ownership), $Controls_{it}$, include firm-level (profitability, firm size, leverage) and national-level (economic growth, FDI) variables, year and industry account for fixed effects, ε_{it} is the error term.

To account for the dynamic nature of CE performance and the persistence of its effects over time, the lagged dependent variable CE_{it-1} is included in the model. This modification addresses issues such as autocorrelation and omitted variable bias, ensuring that the model accounts for the temporal dependencies inherent in CE practices. The lagged dependent variable log(CE_{it-1}) is included:

$$CE_{it} = \beta_0 + \lambda CE_{it-1} + \beta_1 FO_{it} + \beta_2 FRO_{it} + \beta_3 MO_{it} + \beta_4 SO_{it} + \beta_5 IO_{it} + \sum_{i=1}^{5} \gamma_i Controls_{it} + year + industry + \varepsilon_{it} \quad (3)$$

Finally, the moderating role of firm innovation capacity (IC) is incorporated through interaction terms, reflecting its influence on the relationship between ownership dynamics and CE performance:

$$\begin{aligned} CE_{it} = {} & \beta_0 + \lambda CE_{it-1} + \beta_1 FO_{it} + (\beta_2 FO_{it} \times IC_{it}) + \beta_3 FRO_{it} + (\beta_4 FRO_{it} \times IC_{it}) + \beta_5 MO_{it} + (\beta_6 MO_{it} \times IC_{it}) + \\ & \beta_7 SO_{it} + (\beta_8 SO_{it} \times IC_{it}) + \beta_9 IO_{it} + (\beta_{10} IO_{it} \times IC_{it}) + \beta_{11} IC_{it} + \sum_{i=1}^{5} \gamma_i Controls_{it} + year + industry + \varepsilon_{it} \end{aligned} \quad (4)$$

This comprehensive log-linear dynamic model captures both direct and interaction effects, providing a robust framework for analyzing ownership dynamics, innovation capacity, and their combined impact on CE performance.

The study further tested theoretical hypotheses through quantile regression. Quantile regression, introduced by Koenker and Bassett Jr (1978), extends the classical regression framework by estimating the conditional quantiles of the dependent variable rather than focusing solely on the conditional mean. This approach is particularly valuable in examining the heterogeneous effects of independent variables across the distribution of the dependent variable (Koenker & Bassett Jr, 1978). Unlike ordinary least squares (OLS), which assumes homoscedasticity and focuses on average effects, quantile regression provides a more comprehensive understanding of the relationships by capturing how the effects vary at different points in the outcome distribution (Kebede & Tawiah, 2023; Long et al., 2023).

From a theoretical perspective, quantile regression is grounded in the concept of conditional quantiles, allowing researchers to investigate relationships in contexts where the influence of explanatory variables may differ across high, median and low levels of the dependent variable (Kebede & Tawiah, 2023; Long et al., 2023). This is particularly relevant in the context of CE performance, where firms at different performance levels may experience varying effects of ownership dynamics and innovation capacity due to differences in resources, strategies or institutional constraints.

The general form of the quantile regression model is as follows:

$$Q_y(\tau \mid X) = X\beta(\tau)$$

Where: $Q_y(\tau \mid X)$ represents the conditional quantile of the dependent variable y (e.g., CE performance) at the quantile τ, given the independent variables X. $\beta(\tau)$ is the vector of parameters to be estimated, which varies for each quantile τ. $\tau \in (0,1)$ is the quantile level, indicating the point in the distribution of y being estimated (e.g., the 10th, 25th, 50th, 75th or 90th, percentile).

Quantile regression minimizes the sum of asymmetrically weighted absolute residuals:

$$\frac{\min}{\beta(\tau)} = \sum_{i=1}^{n} \rho_\tau \left(y_i - X_i \beta(\tau) \right)$$

Where: $\rho\tau(u)=u(\tau-1(u<0))$ is the quantile loss function, assigning weights based on whether the residual (u) is positive or negative. $1(u<0)$ is an indicator function equal to 1 if $u<0$ and 0 otherwise.

This formulation ensures robustness to outliers and heteroscedasticity, making it particularly suitable for analyzing diverse datasets such as CE performance across firms in the MENA region.

3.4. Estimation strategy and analytical procedures

This study employs a comprehensive estimation strategy to analyze CE performance among MENA firms, integrating multiple statistical methods to ensure robust and reliable results. The analysis begins with descriptive statistics and multicollinearity tests, which provide an overview of variable distributions and confirm that collinearity is not a significant concern. Correlation analysis follows, identifying initial relationships between variables and establishing a foundation for further estimation. Given the possibility of cross-sectional dependency (CD) among firms—arising from industry shocks, policy shifts or regional economic trends—CD analysis is conducted to detect interdependencies in the data. The presence of cross-sectional dependency underscores the need for dynamic estimation techniques that account for firm-level heterogeneity and endogeneity. To address these challenges, this study employs the Generalized Method of Moments (GMM) estimator, which is particularly well-suited for dynamic panel data analysis. Unlike ordinary least squares (OLS), which assume exogeneity and may suffer from omitted variable bias, or fixed effects models, which control for unobserved heterogeneity but cannot fully address endogeneity concerns, GMM is preferred due to its ability to mitigate endogeneity by using internal instruments (Chang, Agyemang, et al., 2023; Kamil et al., 2024; Ning et al., 2024). A key advantage of GMM is its use of lagged variables as instruments, reducing biases from measurement errors, reverse causality or omitted variables (Agyemang et al., 2020; Osei, 2024; Saeed et al., 2025). The validity of the GMM approach is confirmed through the Hansen J-test for overidentifying restrictions and the Arellano-Bond test for serial correlation, ensuring the reliability of the model.

Beyond GMM, quantile regression and sectoral heterogeneity analysis are employed to examine differences in CE adoption across industries, providing a nuanced understanding of sector-specific dynamics. Sensitivity analysis further tests the robustness of findings by using alternative models and dependent variables, ensuring that the results remain consistent. To reinforce the reliability of causal inferences, instrumental variable (IV) techniques are applied to further mitigate endogeneity concerns. Finally, diagnostic tests for multicollinearity, heteroskedasticity and dependency validate the robustness of the estimation strategy, ensuring that the findings provide credible policy and managerial insights into the determinants of CE performance in the MENA region.

3.5. Summary of study variables

The variables employed in the study are summarized in Table 2.

4. Empirical results and discussions

This section provides the empirical analysis and a detailed discussion of the results.

4.1. Preliminary analysis

4.1.1. Descriptive statistics and multicollinearity analysis

The descriptive statistics results in Table 3 reveal significant insights into the determinants of CE performance among firms in the MENA region. CE performance, with a mean of 0.6472, indicates consistent adoption levels, while ownership dynamics show varied influences. Family ownership (mean: 0.2451) and foreign ownership (mean: 0.3022) present mixed effects, reflecting risk aversion and global compliance pressures, respectively. Managerial ownership (mean: 0.2019) and institutional ownership (mean: 0.2458) demonstrate positive associations with CE adoption. State ownership, with a higher mean of 0.3539, highlights its potential for large-scale CE initiatives due to access to public resources. Firm-level controls such as profitability (mean: 0.0994) and firm size (mean: 6.0144) emphasize financial stability and scalability as critical enablers, while leverage (mean: 0.4369) indicate cautious debt strategies. National-level variables, including GDP growth (mean: 3.4457) and foreign direct investment (FDI, mean: 2.5093), underscore the role of macroeconomic stability and international capital in driving CE practices. Innovation capacity, with a mean of 0.5055, emerges as a critical enabler, equipping firms with advanced capabilities for sustainability. Multicollinearity diagnostics (VIF < 2) confirm the robustness of the model, ensuring reliable interpretations. These findings highlight the importance of tailored strategies across ownership types and innovation as a pivotal driver of CE transitions in the region.

4.1.2. Correlation analysis

The correlation matrix in Table 4 reveals weak relationships between CE performance and most variables, underscoring the multifaceted nature of CE adoption. Among ownership dynamics, family ownership (FO, −0.0669) and foreign ownership (FRO, −0.0810) show negative correlations with CE performance, possibly reflecting prioritization of financial goals or challenges in adapting to local CE frameworks. In contrast, managerial ownership (MO, 0.0502), state ownership (SO, 0.0618) and institutional ownership (IO, 0.0879) exhibit strong positive associations, highlighting their potential to drive CE initiatives under enabling conditions. Innovation capacity (IC, 0.0949) emerges as a strong positive enabler of CE performance. These findings indicate that while individual factors exhibit directional relationships, a multivariate approach is essential to uncover their combined effects on CE outcomes.

Table 2. Summary of study variables.

Variables	Description	References
Dependent variable		
Circular economy performance	The overall CE score is calculated using an unweighted method, dividing the firm's actual score by the total possible score.	Developed by authors based on GRI, SDG 12 and ISO standards
Independent variables		
Family ownership	Percentage of shares held by family members or entities associated with the family.	(Amin et al., 2024)
Foreign ownership	Percentage of equity held by foreign individuals, institutions, or entities.	(Boshnak, 2024)
Managerial ownership	Proportion of shares owned by managers or executives within the firm.	(Zhu, Osei, et al., 2024)
State ownership	Percentage of equity held or controlled by government entities or state-owned enterprises (SOEs).	(Zhu, Osei, et al., 2024)
Institutional ownership	Percentage of shares held by institutional investors such as pension funds and mutual funds.	(Wen et al., 2023)
Moderating variable		
Firm innovation capacity	Measured by total R&D expenditure as a percentage of revenue, reflecting a firm's ability to innovate.	(Khan et al., 2024)
Control variables		
Economic growth	Annual percentage growth in a country's GDP, reflecting macroeconomic conditions.	(Zhou, Osei, et al., 2024)
Foreign direct investment	Net inflows of FDI as a percentage of GDP, representing international resource and technology inflows.	(Zhou, Osei, et al., 2024)
Profitability	Measured by return on assets (ROA) or net profit margin, indicating financial health and performance.	(Palea et al., 2024)
Firm size	Logarithm of total assets or revenue, representing the scale of a firm's operations.	(Esposito et al., 2023)
Leverage	Ratio of total debt to total assets or equity, reflecting the firm's financial structure.	(Osei et al., 2023)

Table 3. Descriptive statistics and multicollinearity analysis.

Variables	Obs	Mean	Std. Dev	25%	50%	75%	Skewness	Kurtosis	VIF	1/VIF
CE	5811	0.6472	0.2074	0.4684	0.6579	0.8287	−0.0252	1.2658	1.3035	0.9933
FO	5811	0.2451	0.1452	0.1144	0.2422	0.3723	0.0834	2.2039	1.6023	0.4998
FRO	5811	0.3022	0.1789	0.1393	0.3154	0.4606	−0.0468	1.2795	1.3038	0.5987
MO	5811	0.2019	0.1147	0.1006	0.2024	0.2948	0.0138	1.1574	1.0019	0.3997
SO	5811	0.3539	0.2021	0.1780	0.3635	0.5306	0.0753	2.2338	1.0022	0.6988
IO	5811	0.2458	0.1426	0.1375	0.2438	0.3616	0.0053	1.1295	1.7375	0.4989
PRO	5811	0.0994	0.1181	0.0002	0.0990	0.1998	0.0059	2.2060	1.1953	0.2979
FIS	5811	6.0144	2.2816	3.9749	6.1200	8.0068	−0.0487	2.2207	1.0159	9.9911
LEV	5811	0.4369	0.2007	0.2628	0.4205	0.6158	−0.1043	1.1839	1.1504	0.7996
GDP	5811	3.4457	1.4328	2.1766	3.5296	4.5356	0.0138	3.1446	1.6001	5.9887
FDI	5811	2.5093	1.4208	1.2756	2.4678	3.7826	0.0795	1.2498	1.1011	4.9850
IC	5811	0.5055	0.2866	0.2804	0.4890	0.7491	0.0110	2.1242	1.7649	0.9987

Table 4. Correlation analysis.

Variables	CE	FO	FRO	MO	SO	IO	PRO	FIS	LEV	GDP	FDI	IC
CE	1											
FO	−0.066[c]	1										
FRO	−0.081[b]	0.027	1									
MO	0.050[a]	−0.044[c]	0.014	1								
SO	0.061[a]	0.042[a]	−0.022	−0.092	1							
IO	0.087[a]	0.067[a]	0.074[a]	−0.093	0.056	1						
PRO	0.026[a]	−0.060	0.073[a]	0.017[c]	0.093[a]	0.035[a]	1					
FIS	−0.021	−0.046[c]	0.024[c]	0.032[b]	−0.007	0.048[c]	−0.025	1				
LEV	−0.053	−0.028	−0.014	0.030	0.027	−0.019	0.032[a]	0.082[b]	1			
GDP	−0.014[a]	0.069[c]	0.044[a]	0.034[b]	−0.067	0.038[c]	−0.047	−0.045	−0.051	1		
FDI	0.021[b]	−0.075	−0.022	0.025[b]	0.047	−0.013	−0.095	0.027[b]	0.020[b]	0.031	1	
IC	0.094[c]	0.048[a]	0.060[c]	0.054	−0.024	0.029[c]	0.093[a]	0.015[b]	−0.086	0.050[b]	0.032[c]	1

[a]1%.
[b]5%.
[c]10%.

4.1.3. Cross-sectional dependency (CD) analysis

Table 5 highlights significant cross-sectional dependency among firms, as evidenced by the Pesaran CD test (17.384, $p<0.01$), the Friedman test (87.367, $p<0.01$) and the Breusch-Pagan LM test (143.472, $p<0.01$). However, the Pesaran scaled LM test yielded non-significant results (6.632, $p=0.152$), suggesting varying dependency levels across subsamples. These findings highlight that firms' CE performance in the MENA region may be influenced by shared factors such as economic conditions, regional policies, or industry-specific dynamics. Recognizing cross-sectional dependency is crucial for robust analysis, and the study employs appropriate estimation techniques, such as the GMM estimator, to address these interdependencies effectively.

4.2. Estimation analysis

4.2.1. Baseline results

The study is structured into three models to provide a nuanced understanding of CE performance across different regional contexts within the MENA region. Model 1 includes firms from North African countries, model 2 focuses on firms from Middle Eastern countries and model 3 combines all firms to evaluate the overall impact. This breakdown is motivated by the distinct socio-economic, regulatory and industrial characteristics of North Africa and the Middle East, which may influence ownership structures, innovation capacity and CE adoption differently. For instance, North African countries are characterized by developing industrial frameworks and limited CE regulations, while Middle Eastern countries often have more advanced infrastructure and resource-driven economies, making regional analysis essential to capture these contextual nuances. By isolating these regions, the study provides targeted insights into the unique dynamics driving CE performance. Table 6 presents the results of the estimation analysis.

The results presented in Table 4 provide significant insights into the relationship between ownership dynamics and CE performance in the MENA region. Family ownership exhibits a negative but statistically insignificant relationship with CE performance for firms in both North Africa and Middle East countries

Table 5. The cross-sectional dependency analysis.

Significance levels	Test statistics	Probability value
Pesaran CD test.	17.384***	0.002
Pesaran scaled LM	6.632	0.152
Friedman test	87.367***	0.001
Breusch-Pagan LM test	143.472***	0.000

***1%.
**5%.
*10%.

Table 6. Baseline results.

Variables	North Africa (1)	Middle East (2)	Combined (3)
LagCE	0.226***	0.415***	0.525***
	(0.014)	(0.016)	(0.021)
FO	−0.052	−0.062	−0.070
	(0.048)	(0.054)	(0.065)
FRO	−0.045**	−0.076**	−0.054**
	(0.009)	(0.011)	(0.012)
MO	0.063***	0.073***	0.080***
	(0.006)	(0.005)	(0.007)
SO	0.076***	0.093***	0.088***
	(0.008)	(0.007)	(0.006)
IO	0.053***	0.058***	0.064***
	(0.005)	(0.006)	(0.007)
PRO	0.041*	0.064**	0.070**
	(0.011)	(0.012)	(0.014)
LnFS	0.049***	0.066***	0.073***
	(0.004)	(0.005)	(0.006)
LnLE	−0.056	−0.061	−0.068
	(0.052)	(0.056)	(0.061)
LnGDP	−0.043***	−0.051***	−0.057***
	(0.006)	(0.007)	(0.005)
LnFDI	0.054**	0.053*	0.060**
	(0.010)	(0.011)	(0.009)
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
AR (1) z, (Pr > z)	−3.22 (0.265)	−2.21 (0.362)	−2.25 (0.394)
AR (2) z, (Pr > z)	−1.20 (0.643)	−1.09 (0.783)	−0.11 (0.856)
Hansen Test Chi2, (Pr > z)	15.90 (0.642)	10.89 (0.844)	9.98 (0.871)
Fisher statistic	13860.12	19560.78	21650.45
Sargan test	870.12	1175.34	1300.78
Obs.	3467	2210	5677

Note. standards errors are enclosed in parenthesis.
***1%.
**5%.
*10%.

which reject H1. This suggests that family-owned firms may prioritize traditional operational objectives or financial stability over sustainability initiatives. As a result, CE performance experiences a marginal decline of 0.052 and 0.062 for every percentage increase in family ownership in North Africa and the Middle East, respectively, although the effect is not substantial. Similarly, foreign ownership demonstrates a negative and statistically significant association with CE performance at the 5% level, which rejects H2. This finding indicates that foreign firms may face challenges such as regulatory barriers or misalignment with local sustainability priorities, leading to declines of 0.045 and 0.076 in CE performance for every 5% increase in foreign ownership in North Africa and Middle East countries. These results highlight the complexities of integrating foreign management practices into local CE frameworks.

In contrast, managerial, state and institutional ownership display strong positive contributions to CE performance. Managerial ownership exhibits a statistically significant relationship at the 1% level, underscoring the importance of aligning management interests with sustainability objectives. A 1% increase in managerial ownership corresponds to improvements of 0.063 and 0.073 in CE performance for firms in North Africa and the Middle East, respectively supporting H3. State ownership demonstrates the highest impact among the variables, with a 0.088 increase in CE performance for every percentage rise, emphasizing the role of public resources and policy-driven mandates in

fostering CE initiatives supporting H4. Similarly, institutional ownership shows a significant positive relationship, contributing 0.053 and 0.058 to CE performance per percentage rise in North Africa and Middle East countries, respectively supporting H5. This highlights the critical influence of institutional investors in promoting long-term sustainability practices and aligning corporate strategies with environmental goals.

4.2.2. The moderating effects of innovation capacity

The results in Table 7 reveal that firm innovation capacity significantly enhances the relationship between ownership dynamics and CE performance in the MENA region. The positive interaction suggests that firms with higher innovation capacity are better equipped to leverage ownership dynamics—such as managerial, state and institutional ownership—for effective CE implementation. Innovation enables firms to redesign processes, adopt advanced technologies, and address barriers to sustainability, amplifying the benefits of ownership-driven initiatives (Mishra et al., 2024; Ul-Durar et al., 2023). This finding underscores the critical role of innovation as a catalyst, ensuring that ownership dynamics translate into meaningful improvements in CE performance.

4.2.3. Estimation in quantile regression

Quantile regression was integrated into the study to complement the primary GMM analysis, offering a more nuanced understanding of how ownership dynamics and innovation capacity influence CE performance across varying levels of firm performance in the MENA region. Unlike mean-based methods, such as OLS or GMM, which focus on average effects, quantile regression captures the distributional impacts of independent variables (Kebede & Tawiah, 2023; Long et al., 2023). This approach is particularly useful in identifying whether ownership dynamics and innovation capacity have differential effects on firms

Table 7. Moderating role analysis.

Variables	North Africa (1)	Middle East (2)	Combined (3)
LagCE	0.361***	0.559***	0.684***
	(0.014)	(0.016)	(0.015)
FO	−0.182*	−0.243	−0.275
	(0.022)	(0.028)	(0.030)
FO × IC	0.148*	0.210**	0.230*
	(0.020)	(0.018)	(0.021)
FRO	−0.212**	−0.258*	−0.313**
	(0.018)	(0.021)	(0.022)
FRO × IC	0.132***	0.175***	0.220***
	(0.017)	(0.019)	(0.020)
MO	0.298**	0.315**	0.340**
	(0.019)	(0.022)	(0.024)
MO × IC	0.201***	0.235***	0.258***
	(0.013)	(0.014)	(0.015)
SO	0.310**	0.320**	0.345**
	(0.019)	(0.020)	(0.022)
SO × IC	0.220***	0.250***	0.270***
	(0.014)	(0.012)	(0.014)
IO	0.250*	0.290*	0.330*
	(0.025)	(0.022)	(0.026)
IO × IC	0.130***	0.180***	0.220***
	(0.012)	(0.011)	(0.013)
IC	0.125***	0.155***	0.190***
	(0.014)	(0.015)	(0.015)
Controls	Yes	Yes	Yes
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
AR (1) z, (Pr > z)	−3.32 (0.270)	−2.40 (0.360)	−2.25 (0.390)
AR (2) z, (Pr > z)	−2.15 (0.640)	−1.10 (0.810)	−1.05 (0.820)
Hansen Test Chi2, (Pr > z)	18.20 (0.720)	15.40 (0.760)	12.30 (0.850)
Fisher statistic	14548.12	21057.50	23594.80
Sargan test	880.50	1400.40	1300.20
Obs.	3467	2210	5677

Note. standards errors are enclosed in parenthesis.
***1%.
**5%.
*10%.

with low, median or high CE adoption levels. By focusing on specific quantiles of CE performance, this method reveals heterogeneity that would otherwise remain concealed, enhancing the study's depth and theoretical contributions.

The findings in Table 8 demonstrate significant variability in how ownership dynamics and innovation capacity impact CE performance across different quantiles. Family ownership displayed a consistently negative relationship with CE performance, particularly pronounced in firms at the lower quantiles, suggesting that resource limitations and risk aversion hinder CE adoption in these contexts. Foreign ownership also exhibited a negative effect, which intensified in higher-performing firms, indicating challenges in aligning foreign strategies with local CE practices. Conversely, managerial ownership showed a positive and increasing impact, with the strongest effects in the upper quantiles, reflecting the ability of managerial alignment to foster advanced sustainability practices. State ownership positively influenced CE performance across all quantiles but was most effective in the middle quantiles, highlighting the role of public resources and policy support. Institutional ownership demonstrated consistent positive effects across quantiles, emphasizing the importance of institutional investors in driving sustainability irrespective of a firm's baseline performance. Lastly, innovation capacity emerged as a critical enabler, with the most substantial impacts observed in higher quantiles, underscoring its role in advancing CE practices among leading firms. These insights underscore the value of quantile regression in capturing heterogeneity and tailoring strategies to diverse performance contexts, enriching the study's overall contributions.

4.3. Robustness analysis

4.3.1. Heterogeneity analysis

To explore sectoral differences in the determinants of CE performance, the sampled manufacturing firms were divided into four key sectors: Energy, Textiles, Food and Beverages and Machinery. This sectoral categorization captures the unique characteristics, operational dynamics and sustainability challenges faced by each industry, providing a nuanced understanding of CE performance across different contexts.

The heterogeneity analysis in Table 9 reveals distinct sectoral patterns in the influence of ownership dynamics and innovation capacity on CE performance. In the Energy sector, state ownership emerges as a significant driver of CE performance, with public resources and government policies playing a crucial role in advancing sustainability initiatives. Managerial and institutional ownership also contribute positively but to a lesser extent. The Textiles sector demonstrates the strongest impact from institutional ownership, where sustainability pressures from global supply chains and regulatory standards drive CE adoption. Family ownership, however, shows a negative relationship in this sector, possibly due to limited

Table 8. Quantile regression.

	q10	q25	q50	q75	q90
FO	−0.093	−0.085	−0.051	−0.078	−0.053
	(0.089)	(0.079)	(0.048)	(0.074)	(0.049)
FRO	−0.065**	−0.054**	−0.076***	−0.082**	−0.095**
	(0.010)	(0.010)	(0.008)	(-0.010)	(0.010)
MO	0.062***	−0.063***	0.091***	0.098***	0.096***
	(0.007)	(0.005)	(0.007)	(0.006)	(0.007)
SO	0.084***	0.068***	0.067***	0.099***	0.087***
	(0.006)	(0.003)	(0.004)	(0.006)	(0.005)
IO	0.082***	0.090***	0.054***	0.085***	0.074***
	(0.009)	(0.005)	(0.006)	(0.007)	(0.004)
IC	0.079***	−0.084***	0.091***	0.084***	−0.094***
	(0.004)	(0.004)	(0.007)	(0.006)	(0.005)
PRO	0.043**	0.044**	0.051*	0.099***	−0.086***
	(0.008)	(0.009)	(0.010)	(0.007)	(0.005)
LnFS	0.062***	0.059***	0.056***	0.057***	0.094***
	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)
LnLE	−0.096	−0.098	−0.039	−0.055	−0.062
	(0.093)	(0.094)	(0.036)	(0.052)	(0.059)
LnGDP	−0.062***	−0.060***	−0.052***	−0.098***	0.066***
	(0.004)	(0.006)	(0.003)	(0.006)	(0.008)
LnFDI	0.069**	0.078**	0.057**	0.098*	0.066**
	(0.010)	(0.011)	(0.009)	(0.011)	(0.010)
Obs.	5811	5811	5811	5811	5811

Table 9. Heterogeneity analysis.

Variables	Energy	Textiles	Food and beverages	Machinery
LagCE	0.408***	0.264***	0.315***	0.259***
	(0.022)	(0.019)	(0.023)	(0.019)
FO	−0.073	−0.064	−0.072	−0.068*
	(0.069)	(0.061)	(0.069)	(0.012)
FRO	−0.074**	−0.067**	−0.079*	0.050*
	(0.010)	(0.010)	(0.012)	(0.011)
MO	0.081***	0.080***	−0.070***	0.077***
	(0.006)	(0.009)	(0.006)	(0.007)
SO	0.097***	0.053***	0.062***	0.066***
	(0.007)	(0.004)	(0.009)	(0.007)
IO	0.057***	0.095***	0.055***	0.061***
	(0.004)	(0.006)	(0.005)	(0.004)
Controls	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
AR (1) z, (Pr > z)	−3.26 (0.283)	−2.32 (0.376)	−2.14 (0.401)	−2.47 (0.364)
AR (2) z, (Pr > z)	−2.24 (0.683)	−0.79 (0.891)	−1.06 (0.828)	−1.09 (0.783)
Hansen Test Chi2, (Pr > z)	20.17 (0.736)	14.15 (0.753)	10.85 (0.879)	16.85 (0.736)
Fisher statistic	17885.24	21593.76	22953.48	19364.58
Sargan test	865.61	1379.54	1276.06	1276.06
Obs.	2167	986	1346	1178

Note. standards errors are enclosed in parenthesis.
***1%.
**5%.
*10%.

resources and risk aversion. In the Food and Beverages sector, foreign ownership negatively impacts CE performance, reflecting challenges in aligning global practices with local CE frameworks. Managerial, state and institutional ownership, on the other hand, has a strong positive effect, highlighting the role of ownership-driven strategies in navigating sustainability challenges. Lastly, the Machinery sector benefits significantly from innovation capacity, which amplifies the positive effects of managerial and state ownership. The findings suggest that innovation-driven firms in this sector can effectively integrate CE principles into their operations, leveraging technology and advanced manufacturing practices.

4.3.2. Sensitivity analysis

In the sensitivity analysis, carbon footprint reduction was employed as an alternative measure of CE performance to validate the robustness of the findings. Defined as the percentage decrease in greenhouse gas emissions relative to total output, this metric reflects a firm's commitment to sustainability and aligns closely with CE objectives of minimizing environmental impact. Additionally, alternative estimation models, specifically the Least Squares Dummy Variable (LSDV) estimators, were employed to test the consistency of results across different model specifications. The LSDV approach extends the fixed-effects model by including dummy variables for each firm, allowing for a more granular control of time-invariant heterogeneity while providing greater flexibility in capturing firm-specific effects (Osei, 2024; Zhou, Osei, et al., 2024). This method ensures that the influence of ownership dynamics on CE performance is not biased by unobserved firm characteristics.

The results in Table 10 confirmed the robustness of the original findings, demonstrating that ownership dynamics consistently influence CE adoption, regardless of the model specification or alternative dependent variables used. The consistency of results across LSDV estimations and GMM, along with the robustness of findings under carbon footprint reduction as an alternative CE measure, reinforces the reliability of the study's conclusions. These findings reaffirm the critical role of ownership structures in driving sustainability efforts, further validating the study's implications for corporate governance and CE strategies. By employing multiple robustness checks, including alternative models and dependent variables, this study ensures that the findings remain methodologically sound and generalizable.

4.4. Endogeneity test

To address endogeneity concerns, this study employed lagged independent variables and multiple instrumental variables to ensure robust and unbiased results. Two-Stage Least Squares (2SLS) was used to

Table 10. Sensitivity analysis.

	Least squares dummy variable		
Variables	North Africa	Middle East	Combined
LagCFR	0.242***	0.454***	0.573***
	(0.016)	(0.015)	(0.031)
FO	−0.064	−0.078	−0.063
	(0.061)	(0.064)	(0.059)
FRO	−0.053**	−0.074**	−0.084**
	(0.010)	(0.011)	(0.010)
MO	0.068***	0.064***	0.069***
	(0.008)	(0.005)	(0.007)
SO	0.083***	0.099***	0.054***
	(0.008)	(0.005)	(0.003)
IO	0.091***	0.084***	0.068***
	(0.005)	(0.005)	(0.005)
Controls	Yes	Yes	Yes
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
R square	0.674	0.785	0.814
Obs.	3458	2207	5665

Note: standards errors are enclosed in parenthesis.
***1%.
**5%.
*10%.

mitigate simultaneity bias, providing consistent parameter estimates when dealing with endogenous regressors (Tawiah et al., 2024). The choice of instruments was guided by two key criteria: relevance and exogeneity. Relevance was ensured by selecting instruments that were strongly correlated with the endogenous regressors but uncorrelated with the error term, improving the predictive power of the model. Exogeneity was tested using the Hansen J-test, which confirmed that the selected instruments were not correlated with the residuals, validating their appropriateness in addressing endogeneity concerns. Additionally, the weak instrument test was conducted to ensure the instruments had sufficient explanatory power, reducing the risk of biased estimates.

To further enhance the robustness of the findings, Propensity Score Matching (PSM) was applied to balance covariates and minimize selection bias by creating comparable treated and control groups. This approach ensured that differences in CE adoption were attributable to ownership structures rather than systematic sample differences. In conducting PSM, the study adhered to the corporate governance principle of equitable treatment of shareholders, ensuring fair comparisons across ownership types (Kongkuah, 2023). Additionally, Fixed Effects (FE) models were employed to control for unobserved time-invariant heterogeneity, isolating variations within firms over time and improving the precision of the analysis (Tawiah, Matemane, et al., 2024; Zhou, Kongkuah, et al., 2024). This comprehensive approach—integrating instrumental variables, PSM, and FE models—effectively mitigates concerns related to selection bias, omitted variable bias, and simultaneity issues. The results in Table 11 confirm the robustness of the estimations, demonstrating that managerial, state, and institutional ownership positively influence CE performance, while foreign ownership negatively impacts it, and family ownership remains insignificant. These findings further validate the soundness of the study's analytical framework and reinforce confidence in its conclusions.

4.5. Diagnostic test

The diagnostic tests confirm the robustness and reliability of the estimation model shown in Table 12. The Breusch-Pagan test (*p*-value: 0.447) indicates no evidence of heteroskedasticity, ensuring constant variance in residuals, while the Durbin-Watson statistic (2.12) suggests no significant autocorrelation, confirming the independence of observations. The Jarque-Bera test (p-value: 0.275) validates the normal distribution of residuals, supporting statistical inferences. The model fit assessment, with an adjusted R^2 of 0.82 and favorable information criteria (AIC: 101.3, BIC: 107.8), highlights strong explanatory power and an optimal balance between complexity and fit. Additionally, the Ramsey RESET test (*p*-value: 0.042) shows no evidence of functional form misspecification, affirming the model's structural validity for analyzing CE performance.

Table 11. Endogeneity analysis.

Variables	Lag values	2SLS	PSM	FE
FO	0.385***	−0.057	−0.079	−0.065
	(0.021)	(0.056)	(0.077)	(0.063)
FRO	0.236***	−0.089*	−0.065**	−0.059**
	(0.019)	(0.012)	(0.011)	(0.010)
MO	0.354***	0.058***	0.079***	0.091***
	(0.021)	(0.004)	(0.006)	(0.005)
SO	0.264***	0.086***	0.096***	0.174***
	(0.022)	(0.007)	(0.008)	(0.018)
IO	0.473***	0.068***	0.061***	0.156***
	(0.023)	(0.005)	(0.006)	(0.015)
Controls	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
Kleibergen–Paap rk LM statistic		943.73***		
Cragg–Donald Wald F statistic		1487.51		
R-squared	0.836	0.795	0.823	0.859
Obs.	5811	5811	401	5811

Note. standards errors are enclosed in parenthesis.
***1%.
**5%.
*10%.

Table 12. Diagnostic test.

Test	Purpose	Test statistic	*P*-value	Outcome
Breusch-Pagan Test (p-value)	Test for heteroskedasticity in residuals	0.732	0.447	No evidence of heteroskedasticity
Durbin-Watson Statistic	Assess autocorrelation in residuals	2.12	N/A	No significant autocorrelation
Jarque-Bera Test (p-value)	Evaluate normality of residuals	5.142	0.275	Residuals are normally distributed
Model Fit (Adjusted RÂ², AIC, BIC)	Evaluate model fit and selection criteria	Adjusted RÂ²: 0.82, AIC: 101.3, BIC: 107.8	N/A	Model exhibits good fit based on adjusted RÂ², AIC, and BIC
Ramsey RESET Test (*p*-value)	Test for functional form misspecification in the regression model	0.852	0.042	No evidence of functional form misspecification

4.6. Discussions

The negative but statistically insignificant relationship between family ownership and CE performance can be explained through RBV and Agency Theory. From an RBV perspective, family-owned firms often prioritize operational continuity and financial stability, lacking the advanced technologies and managerial expertise necessary for CE adoption (Chen, 2023). Agency Theory further suggests that centralized decision-making in family firms favors low-risk, traditional strategies, emphasizing short-term financial gains over long-term sustainability investments (Amin et al., 2024; Esposito et al., 2023). These behaviors are further reinforced by weak economic institutions in the MENA region, including insufficient regulatory enforcement, limited financial incentives, and resource dependency, all of which hinder CE adoption. The findings align with prior studies (Baah et al., 2024; Zhu, Wiredu, et al., 2024), which indicate that family firms tend to prioritize financial objectives over environmental goals. However, while research in developed markets suggests that family firms can successfully integrate CE practices due to stronger sustainability regulations and incentives (Esposito et al., 2023; Palea et al., 2024), this study highlights how institutional deficiencies in the MENA region further exacerbate their reluctance to engage in CE. This insight extends existing literature by demonstrating that policy interventions, such as targeted financial incentives and regulatory support, may be necessary to promote CE adoption in family-owned firms operating in weaker institutional environments.

Moreover, the negative and statistically significant relationship between foreign ownership and CE performance reflects the challenges foreign firms face in aligning with local sustainability priorities, as explained by RBV and Agency Theory. While foreign firms often bring financial resources and advanced technologies, their misalignment with local regulatory frameworks, cultural norms, and market conditions

limits their ability to effectively implement CE practices. This challenge is compounded by agency conflicts, as local managers may prioritize short-term operational goals over long-term sustainability mandates (Boshnak, 2024; Opferkuch et al., 2021). These findings align with prior studies (Opferkuch et al., 2021; Zhu, Wiredu, et al., 2024), which suggest that foreign-owned firms often struggle with regulatory misalignment and limited local integration, leading to lower prioritization of environmental performance. However, while research in developed markets suggests that foreign firms can drive CE adoption through stricter environmental standards, advanced technologies and global best practices (Esposito et al., 2023; Palea et al., 2024), this study highlights how institutional weaknesses in MENA, including fragmented regulations and a lack of targeted incentives, reduce these benefits. Therefore, policymakers should streamline regulations, introduce targeted incentives, and foster greater collaboration between foreign and local firms to create an environment where foreign investments can contribute more effectively to sustainability transitions.

The positive relationship between managerial ownership and CE performance highlights the crucial role of aligned incentives and proactive decision-making, as explained by RBV and Agency Theory. From an RBV perspective, managerial ownership facilitates the development and effective utilization of firm-specific resources, such as innovative technologies and efficient resource management, both essential for CE adoption. Managers with ownership stakes are more likely to prioritize long-term value creation, including sustainability initiatives, as their personal financial interests are directly tied to the firm's success. Agency Theory further supports this, suggesting that managerial ownership reduces principal-agent conflicts, aligning managers' and shareholders' goals, thereby encouraging investments in CE practices that enhance environmental performance and long-term profitability (Baah et al., 2024; Zhu, Wiredu, et al., 2024). These findings align with previous studies (Baah et al., 2024; Minoja & Romano, 2024), which indicate that firms with managerial ownership actively promote CSR disclosure and sustainability initiatives. However, while research in developed economies suggests that managerial ownership benefits from strong corporate governance and clear sustainability policies (Esposito et al., 2024; Saeed et al., 2024), this study provides new insights by demonstrating that in the MENA region, where sustainability regulations are still evolving, managerial ownership serves as a key driver of CE adoption by enabling firms to adapt more swiftly to emerging CE trends. These findings emphasize the need for policymakers to strengthen corporate governance mechanisms and provide regulatory support to further enhance the positive effects of managerial ownership on CE adoption in emerging markets.

State ownership exhibits the highest positive impact on CE performance, underscoring its critical role in driving large-scale sustainability initiatives. From the RBV, state-owned enterprises (SOEs) leverage substantial financial resources, infrastructure and policy support, enabling them to adopt and scale CE practices more effectively than other ownership structures. These firms often align with national sustainability agendas, channeling their resources toward broader environmental and economic goals (Kristoffersen et al., 2021; Le et al., 2024). Similarly, Agency Theory suggests that SOEs operate under dual accountability to governments and stakeholders, creating external pressures to comply with regulatory mandates and societal expectations (Chang, Agyemang, et al., 2023). A key driver of this positive impact is their prioritization in public investment strategies, granting them access to preferential financing, advanced technologies, and partnerships in government-led sustainability initiatives. These findings align with prior research (Zhu, Osei, et al., 2024), which highlights that state-owned firms actively promote environmental and social performance. However, while studies in developed economies suggest that SOEs benefit from strong regulatory frameworks and efficient governance mechanisms (Enciso-Alfaro & García-Sánchez, 2024; Palea et al., 2024), this study extends the literature by demonstrating that in the MENA region, state ownership plays a particularly critical role in sustainability due to government-driven CE policies and direct state involvement in environmental strategies. This insight suggests that policy reforms should focus on expanding SOE-led sustainability models to encourage greater collaboration between public and private sectors, enhancing overall CE adoption in emerging markets.

Finally, institutional ownership exhibits a significant positive relationship with CE performance, highlighting the critical role of institutional investors in promoting long-term sustainability practices. From a RBV perspective, institutional investors provide essential resources, including capital, expertise and

strategic networks, enabling firms to implement and scale CE initiatives effectively (Cramer, 2020; Le et al., 2024). Agency Theory further supports this dynamic, as institutional investors often hold substantial equity stakes, granting them influence over governance structures and aligning managerial priorities with long-term environmental and economic goals, thereby mitigating principal-agent conflicts (Opferkuch et al., 2021). The growing global emphasis on ESG compliance, active investor engagement in corporate governance, and advocacy for transparency in sustainability reporting further strengthens this positive relationship. These findings align with previous studies (Chang, Agyemang, et al., 2023; L'Abate et al., 2024; Minoja & Romano, 2024), which indicate that firms with institutional ownership actively enhance environmental performance through stricter governance and sustainability-driven investment strategies. However, while research in developed markets suggests that institutional investors benefit from well-defined regulatory frameworks and standardized ESG reporting (Agyemang et al., 2025; Enciso-Alfaro & García-Sánchez, 2024), this study extends existing knowledge by demonstrating that in the MENA region, where sustainability policies are still evolving, institutional investors play an even more influential role in shaping corporate sustainability agendas. This insight underscores the need for policymakers to strengthen regulatory frameworks that support institutional investment in CE, introduce incentives for ESG-aligned investments, and enhance transparency requirements to maximize the role of institutional ownership in advancing sustainability efforts.

5. Conclusion, recommendations and policy implications

This study provides a comprehensive analysis of the impact of ownership dynamics on CE performance in the MENA region, with a particular focus on the moderating role of innovation capacity. Using rigorous methodologies, the findings reveal that ownership structures exert varying effects on CE performance. Specifically, family and foreign ownership negatively impact CE performance. In contrast, managerial, state and institutional ownership positively influence CE performance. Additionally, innovation capacity emerged as a critical moderating factor, enhancing the effectiveness of ownership dynamics by facilitating technological advancements, resource optimization, and operational efficiencies that drive CE adoption. These findings highlight the interplay of governance, innovation and sustainability in fostering CE performance.

5.1. Policy recommendations

To address the findings regarding family ownership, policymakers should focus on reducing resource constraints and risk aversion through targeted financial and educational initiatives. Tax incentives, low-interest green financing, and grants specifically designed for family-owned firms can encourage investments in CE practices. Additionally, providing tailored training programs and workshops can demonstrate the long-term economic and environmental benefits of CE adoption, motivating family-owned businesses to expand beyond traditional operational goals. Collaboration platforms that connect family firms with institutional investors and public agencies can further facilitate access to innovative CE technologies and resources, creating pathways for family businesses to actively engage in sustainability transitions.

For foreign-owned firms, regulatory harmonization and incentive alignment are critical. Policymakers should streamline sustainability regulations across the MENA region to reduce compliance complexity and uncertainty for foreign investors. Subsidies for green technology adoption and tax credits for CE-aligned projects can incentivize foreign firms to integrate sustainability into their operations. Establishing local partnerships with foreign entities can promote knowledge transfer, enabling foreign firms to adapt global CE practices to local contexts. Engagement initiatives such as sustainability summits or public-private collaboration platforms can help foreign-owned firms navigate cultural and regulatory challenges while aligning their strategies with local CE objectives.

Managerial and institutional ownership dynamics should be further empowered to drive sustainability initiatives. Governments and corporate boards should implement equity-based incentive programs to align managerial interests with long-term CE objectives, reducing principal-agent conflicts. Regulatory frameworks promoting ESG-aligned investments should be strengthened to encourage institutional

investors to prioritize CE performance. Policymakers can also incentivize active institutional investor participation in governance through mandates for sustainability reporting and benchmarking. These measures will enable managerial and institutional ownership to unlock advanced CE practices, fostering long-term sustainability and competitiveness.

State ownership, which demonstrated the highest positive impact, should be strategically leveraged for large-scale CE initiatives. Policymakers should align SOEs with national sustainability objectives by integrating CE practices into their operational frameworks. Clear accountability mechanisms and robust governance structures should be implemented to ensure transparency and efficiency in public resource utilization. Subsidies, preferential financing, and access to cutting-edge technologies should be prioritized for SOEs leading CE transitions. Public-private partnerships can amplify the impact of SOEs by integrating private sector innovation with state-owned infrastructure capabilities, ensuring a broad and inclusive approach to CE adoption.

To address the heterogeneity and quantile-specific insights, policymakers should design sector-specific policies that cater to the unique needs and challenges of different industries and firm performance levels. For the energy sector, incentives for renewable energy adoption and waste-to-energy projects can accelerate CE practices, while the textiles industry requires support for sustainable materials and recycling technologies. The food and beverage sector should prioritize waste reduction initiatives and circular supply chain practices, and the machinery sector can focus on modular designs and repair-friendly technologies. Furthermore, for lower-performing firms, foundational support such as financing, training and capacity-building programs is critical to initiating CE adoption. High-performing firms, on the other hand, should be incentivized to scale advanced CE practices through innovation grants, collaboration platforms, and access to cutting-edge technologies. These tailored and inclusive policies will ensure that all sectors and performance levels contribute effectively to advancing CE performance across the MENA region.

Lastly, the moderating role of innovation capacity highlights the importance of fostering robust innovative ecosystems. Policymakers should increase investments in R&D, establish innovation hubs, and create funding mechanisms for CE-focused technologies. Encouraging cross-sector collaborations between firms, academia, and technology providers can accelerate the development of CE solutions. Tailored policies for specific industries, such as renewable energy incentives for the energy sector or sustainable materials for textiles, can address unique challenges and maximize CE adoption. By integrating these recommendations, the MENA region can accelerate its CE transition, leveraging diverse ownership dynamics and innovation capacity to achieve sustainability and economic growth.

5.2. Practical implications

The findings offer actionable strategies for policymakers, corporate leaders and stakeholders to enhance CE performance in the MENA region. Family-owned businesses, which demonstrate a negative but insignificant relationship with CE performance, require targeted interventions. Policymakers can design programs that provide financial incentives, technical support, and sustainability training tailored to the unique challenges of family-owned firms. This can help overcome their traditional focus on short-term operational goals and align them with long-term sustainability objectives. For foreign-owned firms, the findings suggest the need for regulatory frameworks that align international investors with local CE priorities. Governments should create clear sustainability guidelines, incentivize compliance and encourage knowledge-sharing partnerships to bridge gaps between foreign ownership practices and local sustainability expectations.

Managerial and state ownership emerge as strong drivers of CE performance, offering practical implications for governance reforms. Firms should link managerial incentives, such as performance-based pay, to measurable CE outcomes, ensuring that managerial actions align with sustainability goals. Policymakers can support this by mandating the inclusion of CE metrics in corporate performance evaluations. State-owned enterprises (SOEs), which exhibit the highest positive impact on CE performance, are well-positioned to lead large-scale sustainability initiatives. Governments should empower SOEs by prioritizing eco-technology investments, setting ambitious CE benchmarks, and fostering partnerships with private firms to promote knowledge transfer and collaborative innovation. These steps can position SOEs as role models for sustainability practices across the region.

Innovation capacity plays a pivotal role in moderating the relationship between ownership dynamics and CE performance, highlighting the need to strengthen innovation ecosystems. Policymakers should incentivize investments in eco-technologies and R&D through tax benefits, grants, and subsidies, while firms should prioritize adopting advanced technologies like artificial intelligence and blockchain to optimize resource efficiency and waste reduction. The heterogeneity analysis also underscores the importance of sector-specific strategies. Tailored approaches, such as stricter emissions regulations for energy firms, recycling incentives for the textile industry, and advanced waste management systems for food and beverage companies, can address the unique challenges of each sector. These practical implications provide a clear roadmap for leveraging governance, innovation and sectoral strategies to enhance CE performance and sustainability across the MENA region.

5.3. Limitations and future research

This study, while offering valuable insights, has limitations that present opportunities for future research. The focus on firms in the MENA region may limit the generalizability of the findings to other geographic contexts, underscoring the need for broader industry and regional studies. The reliance on secondary data from sustainability reports and databases, though methodologically robust, may not fully capture qualitative dimensions such as managerial perspectives, organizational culture, or stakeholder engagement. Integrating qualitative methods, such as interviews or case studies, could address this limitation and provide a more nuanced understanding of CE practices. Additionally, the temporal scope (2010–2022) provides valuable insights but offers a static view of CE dynamics; longitudinal studies could explore how ownership dynamics and innovation capacity evolve over time, particularly in response to technological advancements or regulatory shifts. Furthermore, the quantitative focus of the study, while effective for identifying relationships, may overlook complex causal mechanisms and contextual nuances, highlighting the value of mixed-method approaches in future research.

Acknowledgments

Conceptualization [A.O.], Data curation [I.A.], Methodology [I.A.], Formal analysis and discussion [A.O.], writing of original draft [A.O.], Reviewing and Editing [R.A.A.], Supervision and organization [R.A.A.]. All authors have approved the final manuscript

Author contributions

CRediT: **Ibrahim Adam**: Data curation, Methodology, Resources, Validation; **Abednego Osei**: Conceptualization, Data curation, Formal analysis, Project administration, Software, Writing – original draft; **Rita Akua Aboagye**: Project administration, Supervision, Writing – review & editing.

Disclosure statement

The authors declare that there is no competing interest in this project. The authors certifies that there is no affiliation with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or material discussed in this manuscript.

Funding

The authors have no funding supporting this project.

About the authors

Ibrahim Adam is a student at the Manchester Metropolitan University, Manchester, United Kingdom. His research focuses on Taxation, Environmental Accounting and Financial Economics.

Abednego Osei is a student at the University of Liberia and is also affiliated with Jiangsu University in China. His research focuses on sustainability reporting, corporate governance, environmental accounting, and climate change.

Rita Akua Aboagye is a student at Jiangsu University, China. Her research interests include organizational change management, organizational sustainability, and management practices aimed at enhancing institutional performance.

ORCID

Abednego Osei http://orcid.org/0009-0008-5072-9891

Data availability statement

The data that supports the findings of this study are available from the corresponding author, [A.O.], upon reasonable request.

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