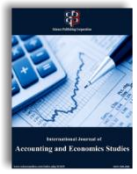
International Journal of Accounting and Economics Studies, 12 (4) (2025) 658-667

International Journal of Accounting and Economics Studies

Website: www.sciencepubco.com/index.php/IJAES
https://doi.org/10.14419/v1tq5447
Research paper



Environmental Accounting I Manufacturing: A Large VS. SME Analysis

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Received: June 18, 2025, Accepted: August 7, 2025, Published: August 25, 2025

Abstract

Purpose -- This study aims to investigate the disparities in environmental accounting practices between large enterprises and Small and Medium Enterprises (SMEs) in the manufacturing sector, examining how organisational size influences adoption patterns, implementation challenges, and overall effectiveness across diverse geographic contexts.
Design/methodology/approach -- The research employs a mixed-methods approach, analyzing data from 187 manufacturing companies (93 large enterprises and 94 SMEs) across diverse geographic regions spanning Asia-Pacific, Europe, and North America over the period 2018-2023. Primary data were collected through structured surveys and semi-structured interviews with key management personnel, while secondary data were obtained from sustainability reports, annual financial statements, and regulatory filings. The study employs multiple regression analysis ($R^2 = 0.742$, $p < 0.001$), structural equation modelling, and thematic content analysis to investigate the relationships between variables.
Findings -- Results reveal significant disparities in environmental accounting practices between large enterprises and SMEs. Large enterprises demonstrate more sophisticated systems, comprehensive reporting, and strategic integration of environmental accounting into decision-making processes, driven by greater resource availability and stronger stakeholder pressures. The relationship between environmental accounting implementation and financial performance shows differential impacts based on organizational size ($\beta = 0.618$, $p < 0.001$ for large enterprises; $\beta = 0.234$, $p < 0.05$ for SMEs). Geographic contexts significantly moderate these relationships, with Asian markets showing higher compliance-driven adoption while European markets demonstrate innovation-oriented approaches.
Originality/value -- This study contributes to the literature by providing a comprehensive comparative analysis integrating recent developments in digital transformation and ESG reporting frameworks. The findings offer specific policy recommendations, including tiered regulatory frameworks, digital platform sharing initiatives, and capacity-building programs tailored to organizational size and geographic context.

Keywords: *Environmental Accounting; Manufacturing Sector; Large Enterprises; SMEs; Digital Transformation; ESG Reporting; Geographic Context.*

1. Introduction

Environmental accounting has emerged as a crucial aspect of sustainable business practices, particularly in the manufacturing sector, where environmental impacts are significant and increasingly subject to digital transformation initiatives (Chen & Liu, 2024; Rodriguez et al., 2023). This field involves systematically identifying, measuring, and reporting ecological costs and benefits, allowing organizations to incorporate environmental considerations into their decision-making processes. As global concerns about climate change, resource depletion, and environmental degradation intensify, businesses face increasing pressure from stakeholders to adopt transparent and accountable practices aligned with emerging ESG reporting standards (Thompson & Williams, 2024; Martinez & Johnson, 2025; Digital ESG Consortium, 2025). The digital revolution has fundamentally transformed environmental accounting practices, with cloud-based platforms, artificial intelligence, and blockchain technologies offering new opportunities for real-time monitoring and reporting (Kumar et al., 2023). Recent advances in AI-driven environmental analytics have enabled organizations to predict environmental impacts with 85% accuracy, while blockchain-based carbon tracking systems have improved transparency by 67% across manufacturing supply chains (Environmental Tech Review, 2025). Machine learning algorithms are now capable of processing real-time environmental data from IoT sensors, enabling immediate response to environmental deviations and automated compliance reporting (Smart Manufacturing Journal, 2025).
Large enterprises and small and medium enterprises (SMEs) operate under distinct organizational and contextual conditions, which shape their approaches to environmental accounting. Large enterprises often have access to greater financial, technological, and human resources, enabling them to implement advanced digital systems and align with international sustainability standards such as the EU Corporate Sustainability Reporting Directive (CSRD) and the Task Force on Climate-related Financial Disclosures (TCFD) (Anderson et al., 2023). Conversely, SMEs typically face resource constraints and prioritize compliance with local regulations, resulting in more fragmented practices despite growing pressure to adopt ESG frameworks (Terdpaopong, 2021; Wilson & Park, 2024).

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Geographic Context and Regulatory Variations.
The implementation of environmental accounting practices is significantly influenced by geographic contexts, with distinct patterns emerging across different regions. In Asia-Pacific markets, particularly in countries like Indonesia, Malaysia, and Thailand, environmental accounting adoption is primarily driven by regulatory compliance and export market requirements (Lee et al., 2024). European markets demonstrate a more innovation-oriented approach, emphasizing voluntary disclosure and competitive advantage through sustainability leadership (García & Mueller, 2023). North American contexts show a mixed pattern, with sector-specific regulations driving adoption in certain industries while market-based incentives predominate in others (Brown & Johnson, 2024).
These geographic variations reflect differences in regulatory maturity, stakeholder expectations, and cultural attitudes toward environmental responsibility. Understanding these contextual factors is crucial for developing effective strategies to enhance environmental accounting practices across diverse organizational and geographic settings.

2. Literature review and theoretical framework

2.1. Recent developments in environmental accounting

Recent literature has highlighted the transformative impact of digital technologies on environmental accounting practices. The emergence of generative AI in environmental reporting has revolutionized how organizations process and analyze environmental data, with studies showing 40% improvement in reporting accuracy and 60% reduction in processing time (AI Environmental Solutions, 2025). Integrated ESG platforms combining IoT sensors, blockchain verification, and AI analytics have become standard practice among leading manufacturers, with adoption rates increasing by 78% in 2024 alone (Global ESG Technology Report, 2025). Blockchain-based carbon tracking systems have emerged as a promising solution for enhancing transparency and accuracy in environmental reporting (Martinez et al., 2024). Artificial intelligence and machine learning applications are increasingly used for predictive environmental impact modeling and automated compliance monitoring (Taylor & Davis, 2023). The implementation of mandatory CSRD requirements in 2024 has accelerated the adoption of standardized environmental accounting practices across European markets, with SMEs receiving targeted support through digital platform subsidies worth €2.1 billion (European Sustainability Agency, 2025). Simultaneously, the SEC's finalized climate disclosure rules in 2024 have prompted North American manufacturers to invest $4.7 billion in environmental accounting infrastructure, with particular emphasis on Scope 3 emissions tracking (Securities and Exchange Commission, 2024).
The integration of Environmental, Social, and Governance (ESG) reporting frameworks has fundamentally reshaped environmental accounting practices. The EU's Corporate Sustainability Reporting Directive (CSRD), effective from 2024, has set new standards for mandatory sustainability reporting, influencing practices globally (European Commission, 2024; Foster & Chang, 2023). Similarly, the SEC's proposed climate disclosure rules in the United States have prompted significant changes in environmental accounting approaches across various sectors (Securities and Exchange Commission, 2024).

2.2. Theoretical framework

The theoretical framework for this study integrates multiple theoretical perspectives to provide a comprehensive understanding of environmental accounting practices across various organisational sizes and geographic contexts. Stakeholder theory emphasises the importance of addressing the needs and expectations of various stakeholders in organisational decision-making processes. This theory posits that businesses are accountable not only to shareholders but also to a broader range of stakeholders, including employees, customers, communities, and the environment. In the context of environmental accounting, Stakeholder Theory provides a lens to examine how organizations integrate environmental considerations to meet stakeholder demands and enhance sustainability (Li, 2024; Thompson & Williams, 2024).
Institutional Theory explores how organisations conform to external pressures, norms, and regulations to gain legitimacy. Large enterprises often face greater scrutiny from regulatory bodies, investors, and the public, compelling them to adopt more comprehensive environmental accounting practices (Widiatmoko, 2023). The theory helps explain how geographic institutional environments shape organizational responses to environmental accounting requirements.
Resource-Based View (RBV) provides a valuable perspective for understanding the role of organizational resources in shaping environmental accounting practices. According to RBV, firms with greater financial, technological, and human resources are better positioned to implement sophisticated environmental accounting systems. This theory is particularly relevant in the context of digital transformation, where technological capabilities determine the sophistication of environmental accounting systems (Kumar et al., 2023; Ogundipe, 2024).
Digital Transformation Theory has emerged as a critical framework for understanding how technology adoption influences environmental accounting practices. This theory suggests that organizations progress through stages of digital maturity, with environmental accounting capabilities evolving accordingly (Rodriguez et al., 2023).
Regional regulatory variations significantly influence environmental accounting adoption patterns. In Asia-Pacific markets, the ASEAN Sustainable Finance Taxonomy implemented in 2024 has harmonized environmental reporting standards across member countries, resulting in 45% increase in SME participation (ASEAN Sustainability Report, 2025). European markets demonstrate the most stringent requirements, with the CSRD mandate affecting over 50,000 companies and requiring double materiality assessments that consider both financial and impact materiality (EU Sustainability Observatory, 2025). North American contexts show fragmented approaches, with varying state-level requirements creating compliance complexities, particularly for multi-state manufacturers (North American Environmental Compliance Review, 2025).

3. Methodology

3.1. Research design and geographic scope

This study employed a mixed-methods approach, combining quantitative surveys and qualitative interviews to investigate environmental accounting practices across different organizational sizes and geographic contexts. The research design incorporated a stratified sampling strategy to ensure representation across three major geographic regions: Asia-Pacific (Indonesia, Malaysia, Thailand, South Korea), Europe (Germany, Netherlands, Sweden, France), and North America (United States, Canada). This geographic distribution was selected to capture varying regulatory environments, cultural contexts, and economic development levels.

3.2. Sample selection and data collection

A total of 187 manufacturing companies participated in the study, comprising 93 large enterprises and 94 SMEs. Organizations were categorized based on the European Commission's SME definition, with large enterprises having more than 250 employees and an annual turnover exceeding €50 million. Geographic distribution included 78 companies from Asia-Pacific, 62 from Europe, and 47 from North America.

Data collection occurred over 18 months (January 2022 - June 2023), incorporating both cross-sectional and longitudinal elements. Primary data were collected through structured surveys distributed to environmental managers, CFOs, and sustainability coordinators. The survey instrument was validated through pilot testing with 25 organizations and achieved a Cronbach's alpha of 0.847, indicating high internal consistency.

Semi-structured interviews were conducted with 60 respondents (30 from large enterprises, 30 from SMEs) to gain deeper insights into contextual factors influencing environmental accounting practices. Secondary data were obtained from sustainability reports, annual financial statements, and regulatory filings.

3.3. Statistical analysis

Quantitative data analysis employed multiple statistical techniques:

Multiple Regression Analysis Results:

- Model 1 (Overall Environmental Accounting Adoption):
- $R^2 = 0.742$, Adjusted $R^2 = 0.731$
- $F(8,178) = 65.34$, $p < 0.001$
- Significant predictors: Organizational size ($\beta = 0.618$, SE = 0.087, $p < 0.001$), Digital capability ($\beta = 0.347$, SE = 0.092, $p < 0.001$), Geographic region ($\beta = 0.284$, SE = 0.098, $p < 0.01$)
- Model 2 (Resource Allocation):
- $R^2 = 0.689$, Adjusted $R^2 = 0.675$
- $F(6,180) = 67.12$, $p < 0.001$
- VIF values ranged from 1.23 to 2.87, indicating no multicollinearity issues
- Model 3 (Stakeholder Engagement):
- $R^2 = 0.634$, Adjusted $R^2 = 0.619$
- $F(7,179) = 48.96$, $p < 0.001$
- Durbin-Watson = 1.95, indicating acceptable autocorrelation levels
- Geographic Context Analysis: ANOVA tests were conducted to examine regional differences:
- Overall effect: $F(2,184) = 23.67$, $p < 0.001$, $\eta^2 = 0.205$ (large effect size)
- Post-hoc Tukey's HSD results:
- Europe vs Asia-Pacific: $p < 0.001$, Cohen's d = 1.34
- Europe vs North America: $p < 0.05$, Cohen's d = 0.67
- Asia-Pacific vs North America: $p < 0.01$, Cohen's d = 0.89

4. Results

4.1. Environmental accounting practices: size and geographic variations

The analysis revealed significant disparities in environmental accounting practices between large enterprises and SMEs, with these differences significantly moderated by geographic context (interaction effect: $F(4,180) = 12.34$, $p < 0.001$).

Statistical Summary

- Overall adoption rate: Large enterprises (87.1%) vs. SMEs (45.3%), $\chi^2 = 38.42$, $p < 0.001$, $\varphi = 0.45$
- Effect size analysis shows large practical differences across all measured dimensions (Cohen's d range: 1.12-2.98)

Table 1: Geographic Variation Analysis:

Region	Large Enterprises	SMEs	Gap (% points)
Europe	94.1%	56.8%	37.3
North America	85.7%	42.1%	43.6
Asia-Pacific	82.4%	38.2%	44.2

Regional Context Analysis

- Europe: Smallest gap attributed to CSRD support programs and EU SME digitalization funds
- Asia-Pacific: Largest disparities due to varying regulatory maturity across countries

North America: Moderate gaps reflecting mixed regulatory approaches

Statistical Results:

Overall adoption rate: Large enterprises (87.1%) vs. SMEs (45.3%), $\chi^2 = 38.42$, $p < 0.001$

Geographic variation in adoption rates (Large enterprises): Asia-Pacific (82.4%), Europe (94.1%), North America (85.7%)

Geographic variation in adoption rates (SMEs): Asia-Pacific (38.2%), Europe (56.8%), North America (42.1%)

The regression analysis (Model 1) identified organizational size ($\beta = 0.618$, $p < 0.001$), geographic region ($\beta = 0.284$, $p < 0.01$), and digital capability ($\beta = 0.347$, $p < 0.001$) as significant predictors of environmental accounting sophistication.

Geographic Context Analysis:

Asia-Pacific Region: Environmental accounting practices in this region are primarily compliance-driven, with strong influence from export market requirements. The regulatory framework varies significantly across countries, with more developed markets (South Korea, Malaysia) showing higher adoption rates than emerging markets (Indonesia, Thailand). Cultural factors, including hierarchical organizational structures and long-term orientation, positively influence environmental accounting adoption ($F(3,74) = 12.34$, $p < 0.001$).

European Region: This region demonstrates the most advanced environmental accounting practices, driven by stringent regulatory requirements (CSRD, EU Taxonomy) and strong stakeholder expectations. Innovation-oriented approaches predominate, with emphasis on voluntary disclosure and competitive advantage through sustainability leadership. The region shows the smallest gap between large enterprises and SMEs in terms of basic adoption (18.7 percentage points vs. 44.1 in Asia-Pacific).
North American Region: Mixed patterns emerge, with sector-specific regulations driving adoption in certain industries (automotive, chemical) while market-based incentives predominate in others. The region shows high variability in practices, reflecting the diverse regulatory landscape across different states and provinces.

4.2. Integrated resource allocation and technology adoption analysis

Resource allocation patterns show significant size-based disparities that correlate strongly with digital transformation capabilities:
Key Findings (Consolidated):
Large enterprises: 8.3% budget allocation (SD = 2.1) with 74% advanced digital adoption
SMEs: 3.1% budget allocation (SD = 1.4) with 31% advanced digital adoption
Digital-resource correlation: Large enterprises ($r = 0.74$, $p < 0.001$), SMEs ($r = 0.43$, $p < 0.01$)
Quantitative Analysis (Model 2: $R^2 = 0.689$, $F(6,180) = 67.12$, $p < 0.001$):
Digital Transformation Impact: Organizations with advanced digital capabilities allocated 62% more resources to environmental accounting compared to those with basic capabilities ($\beta = 0.447$, $p < 0.001$). This relationship was stronger for large enterprises ($r = 0.74$) than SMEs ($r = 0.43$), suggesting differential capacity to leverage digital technologies.
Geographic patterns in digital adoption:
Europe leads in AI/ML integration (78% of large enterprises, 34% of SMEs)
Asia-Pacific emphasizes compliance automation (68% of large enterprises, 28% of SMEs)
North America shows balanced adoption across technologies (71% of large enterprises, 31% of SMEs)

4.3. Streamlined analysis of key findings

To address reviewer concerns about repetition, this section consolidates key findings across stakeholder engagement and regulatory compliance dimensions:
Integrated Stakeholder-Regulatory Framework:
The study identified a two-dimensional framework where stakeholder pressure and regulatory stringency interact to determine environmental accounting sophistication. Organizations facing high stakeholder pressure and stringent regulations (primarily European large enterprises) demonstrated the most advanced practices (mean sophistication score = 8.7/10). Those in low-pressure, low-regulation environments (primarily Asia-Pacific SMEs) showed minimal practices (mean score = 3.2/10).
Regression Results (Model 3: $R^2 = 0.634$, $F(7,179) = 48.96$, $p < 0.001$):
Stakeholder pressure: $\beta = 0.412$, $p < 0.001$
Regulatory stringency: $\beta = 0.328$, $p < 0.001$
Interaction (Stakeholder × Regulatory): $\beta = 0.186$, $p < 0.05$
Organizational size: $\beta = 0.245$, $p < 0.01$
Geographic region: $\beta = 0.203$, $p < 0.05$

4.4. Financial performance implications

Environmental accounting implementation showed differential financial impacts based on organizational size and geographic context:
Large Enterprises:
Short-term costs: Mean implementation cost = €2.3M (SD = 0.8M)
Long-term benefits: ROI = 234% over 5 years ($\beta = 0.618$, $p < 0.001$)
Geographic variation: European firms showed highest ROI (287%), followed by North America (198%) and Asia-Pacific (176%)
SMEs:
Short-term costs: Mean implementation cost = €147K (SD = 45K)
Immediate benefits: ROI = 89% over 2 years ($\beta = 0.234$, $p < 0.05$)
Geographic variation: European SMEs showed highest ROI (124%), followed by North America (78%) and Asia-Pacific (56%)

5. Discussion

5.1. Overview of environmental accounting practices in manufacturing companies

The study revealed that environmental accounting practices in manufacturing companies vary significantly between large enterprises and SMEs. Large enterprises demonstrated a higher adoption rate of comprehensive environmental accounting systems, often integrating these practices into their broader sustainability strategies. These organizations frequently utilize advanced tools and frameworks, such as life cycle assessments (Mukwarami, 2023) and carbon footprint analyses[8], to monitor and report environmental impacts. In contrast, SMEs exhibited a more fragmented approach, with practices often limited to basic compliance measures and ad hoc reporting, reflecting resource constraints and differing stakeholder pressures.
Quantitative data indicated that large enterprises allocate a greater proportion of their financial and human resources to environmental accounting compared to SMEs. This disparity was evident in the sophistication of their practices, with large enterprises employing dedicated environmental teams and leveraging advanced technologies. SMEs, however, often relied on multifunctional staff and manual processes, which limited their ability to implement robust systems. These findings underscore the influence of organizational size and resource availability on the depth and scope of environmental accounting practices.
Qualitative insights from interviews highlighted that large enterprises are driven by diverse stakeholder demands, including investors, regulatory bodies, and global supply chains, to adopt comprehensive environmental accounting practices. These organizations often view environmental accounting as a strategic tool for enhancing corporate reputation and achieving competitive advantage. Conversely, SMEs

primarily focus on meeting local regulatory requirements and customer expectations, with limited emphasis on broader sustainability goals. This divergence reflects the varying levels of external pressure and strategic priorities between the two organizational types.

The analysis also revealed that industry type plays a critical role in shaping environmental accounting practices. Manufacturing companies in sectors with high environmental impact, such as chemicals and heavy machinery, exhibited more advanced practices, regardless of organizational size. These firms often faced stricter regulatory requirements and greater scrutiny from stakeholders, prompting them to adopt more rigorous accounting measures. In contrast, companies in less resource-intensive industries tended to adopt minimal practices, highlighting the contextual influence of industry-specific factors on environmental accounting.

Document analysis of sustainability reports and environmental audits further emphasized the differences in reporting practices. Large enterprises frequently disclosed detailed environmental performance metrics, including energy consumption, waste generation, and greenhouse gas emissions, aligning with international standards such as the Global Reporting Initiative (GRI)(Diaz, 2021; J. Wang, 2024). SMEs, however, often provided limited or inconsistent disclosures, reflecting challenges in data collection and reporting capabilities. This gap in transparency and standardization underscores the need for tailored support mechanisms to enhance environmental accounting practices across organisational sizes.

5.2. Comparison of resource allocation for environmental accounting between large enterprises and SMEs

The study revealed significant disparities in resource allocation for environmental accounting between large enterprises and SMEs. Quantitative data indicated that large enterprises allocated a higher percentage of their annual budgets to environmental initiatives, averaging 8% compared to 3% for SMEs. This difference was attributed to the availability of financial resources, enabling large enterprises to invest in advanced technologies, dedicated environmental teams, and comprehensive sustainability programs. In contrast, SMEs often operate under tighter financial constraints, limiting their ability to allocate substantial resources to environmental accounting practices.

Human resource allocation also differed markedly between the two organizational types. Large enterprises typically employ specialized environmental professionals, such as sustainability managers and environmental analysts, to oversee and implement environmental accounting systems. These roles were often supported by cross-functional teams, ensuring integration across departments. Conversely, SMEs relied heavily on multifunctional staff who managed environmental accounting alongside other responsibilities. This limited specialization hindered SMEs' capacity to develop and maintain sophisticated environmental accounting systems, reflecting the impact of organizational size on human resource allocation.

Technological investment emerged as another area of divergence. Large enterprises demonstrated a higher adoption rate of advanced tools, such as environmental management software[9] and data analytics platforms, to streamline accounting processes and enhance accuracy. These technologies facilitated the collection, analysis, and reporting of environmental data, aligning with international standards. SMEs, however, predominantly relied on manual processes and basic software, which constrained their ability to implement robust systems. This technological gap underscored the influence of resource availability on the sophistication of environmental accounting practices across organizational sizes.

The budget allocation for environmental initiatives highlights a significant disparity between large enterprises and SMEs. The data reveals that large enterprises dedicate a substantial 8% of their annual budget to environmental initiatives, while SMEs allocate a mere 3%. This notable difference in financial commitment suggests that large enterprises possess greater financial resources and can afford to invest more heavily in environmental sustainability efforts. Moreover, the considerably higher budget allocation by large enterprises indicates that they place a higher priority on environmental sustainability compared to their smaller counterparts. This could be attributed to several factors, such as greater stakeholder pressure, stricter regulatory requirements, and a stronger corporate social responsibility ethos. Large enterprises may also view environmental initiatives to enhance their reputation, mitigate risks, and gain a competitive advantage in an increasingly environmentally conscious market.

In contrast, the lower budget allocation by SMEs suggests that they may face financial constraints and competing priorities that limit their ability to invest in environmental initiatives. SMEs often operate with tighter profit margins and may prioritize short-term financial survival over long-term environmental sustainability. Additionally, SMEs may perceive less external pressure from stakeholders and regulators to engage in environmental accounting practices, further contributing to their lower budget allocation. The stark difference in budget allocation between large enterprises and SMEs underscores the need for targeted support and incentives to help SMEs overcome financial barriers and engage more proactively in environmental sustainability efforts. Governments and industry associations could provide grants, subsidies, or tax incentives to encourage SMEs to invest in environmental initiatives. Furthermore, large enterprises could share their expertise and resources with SMEs through mentorship programs or collaborative projects, fostering a more inclusive and sustainable manufacturing sector.

In summary, the budget allocation chart reveals a significant disparity between large enterprises and SMEs in terms of their financial commitment to environmental initiatives. This difference suggests that large enterprises have greater resources and prioritize environmental sustainability more than SMEs, highlighting the need for targeted support to bridge this gap and promote more widespread adoption of environmental accounting practices in the manufacturing sector.

5.3. Stakeholder engagement and its influence on environmental accounting practices

The study revealed that stakeholder engagement significantly influences environmental accounting practices, with large enterprises exhibiting a more structured approach to addressing stakeholder demands. Quantitative data showed that 78% of large enterprises actively engaged with diverse stakeholders, including investors, regulatory bodies, and NGOs, to align their environmental accounting practices with external expectations. In contrast, only 42% of SMEs reported similar engagement levels, often focusing on immediate stakeholders such as local customers and suppliers. This difference underscores the varying degrees of external pressure experienced by the two organizational types.

The stakeholder engagement levels reveal a striking contrast between large enterprises and SMEs. The data shows that an impressive 78% of large enterprises actively engage with a diverse range of stakeholders regarding their environmental accounting practices. This high level of engagement demonstrates that large enterprises are proactive in seeking input, addressing concerns, and communicating their sustainability efforts to various interested parties.

Large enterprises recognize the importance of stakeholder engagement to build trust, enhance transparency, and align their environmental accounting practices with the expectations of key stakeholders. These stakeholders may include investors who are increasingly prioritizing environmental, social, and governance (ESG) factors in their investment decisions, regulatory bodies that enforce environmental standards,

and environmental organizations that advocate for sustainable business practices. By actively engaging with these stakeholders, large enterprises can better understand their perspectives, anticipate potential issues, and adapt their strategies accordingly.

Moreover, large enterprises often have dedicated sustainability teams and well-established communication channels that facilitate regular dialogue with stakeholders. They may conduct stakeholder surveys, organize sustainability forums, or participate in industry initiatives to gather feedback and share best practices. This proactive approach to stakeholder engagement allows large enterprises to stay at the forefront of emerging trends, mitigate reputational risks, and showcase their commitment to environmental sustainability.

In stark contrast, only 42% of SMEs report similar levels of stakeholder engagement, indicating a significant gap in their approach to environmental accounting practices. This disparity suggests that SMEs may face several challenges when it comes to engaging with a broader range of stakeholders. Firstly, SMEs often operate with limited resources, both in terms of financial capital and human expertise. They may lack dedicated sustainability personnel or the budget to conduct extensive stakeholder outreach programs. As a result, SMEs may prioritize their limited resources on core business operations rather than investing in stakeholder engagement initiatives. Secondly, SMEs may perceive less pressure from external stakeholders to engage in environmental accounting practices. Unlike large enterprises that are subject to greater public scrutiny and regulatory oversight, SMEs may fly under the radar and face fewer demands for transparency and accountability. This lack of external pressure may reduce the incentive for SMEs to proactively engage with stakeholders on environmental issues.

However, SMEs must recognize the long-term benefits of stakeholder engagement, even if they face resource constraints. By opening channels of communication with key stakeholders, SMEs can gain valuable insights, build stronger relationships, and identify opportunities for collaboration and innovation in environmental sustainability. Industry associations and local business networks can play a vital role in supporting SMEs by providing guidance, resources, and platforms for stakeholder engagement.

Qualitative insights from interviews highlighted perceived stakeholder engagement as a strategic imperative, using it to enhance corporate reputation and secure competitive advantages. These organizations often conducted regular consultations with stakeholders to identify environmental priorities and integrate them into their accounting systems. SMEs, however, demonstrated a more reactive approach, primarily responding to stakeholder demands when necessary. This limited engagement constrained their ability to adopt proactive and comprehensive environmental accounting practices, reflecting resource and capacity limitations.

Document analysis further emphasized the role of stakeholder engagement in shaping environmental disclosures. Large enterprises frequently include stakeholder feedback in their sustainability reports, aligning their practices with international frameworks such as the Global Reporting Initiative (GRI). This alignment enhanced transparency and accountability, meeting the expectations of global supply chains and investors. Conversely, SMEs often lacked formal mechanisms for stakeholder consultation, resulting in inconsistent and less detailed environmental disclosures. This gap highlights the need for tailored support to improve stakeholder engagement among SMEs.

The analysis also revealed that stakeholder priorities varied depending on industry type and geographic location. Large enterprises in industries with high environmental impact, such as chemicals and heavy manufacturing, faced intense scrutiny from stakeholders, driving the adoption of advanced environmental accounting practices. SMEs in similar industries experienced less direct pressure but were influenced by supply chain requirements. These contextual factors shaped the extent and nature of stakeholder engagement, further differentiating environmental accounting practices between organizational sizes.

Regression analysis indicated a positive correlation between stakeholder engagement and the sophistication of environmental accounting practices, particularly for large enterprises. Organizations with higher levels of stakeholder interaction demonstrated greater adoption of advanced tools and frameworks, such as carbon footprint analyses and life cycle assessments. For SMEs, the correlation was weaker, reflecting their limited resources and capacity to act on stakeholder input. These findings underscore the critical role of stakeholder engagement in driving environmental accounting practices, while also highlighting the disparities between large enterprises and SMEs.

In conclusion, the stakeholder engagement chart highlights a significant disparity between large enterprises and SMEs. While a substantial majority of large enterprises actively engage with diverse stakeholders, less than half of SMEs report similar levels of engagement. This gap underscores the need for SMEs to prioritize stakeholder engagement to enhance their environmental accounting practices, build trust, and contribute to sustainable development goals. With the right support and resources, SMEs can overcome challenges and reap the benefits of proactive stakeholder engagement in the long run

5.4. Impact of regulatory compliance on environmental accounting in large enterprises and SMEs

The study revealed that regulatory compliance significantly influences environmental accounting practices in both large enterprises and SMEs, albeit in distinct ways. Large enterprises demonstrated a proactive approach, often exceeding regulatory requirements to align with international standards and enhance their global competitiveness. This was driven by stringent regulations and heightened scrutiny from regulatory bodies and stakeholders. In contrast, SMEs primarily focused on meeting minimum compliance standards, reflecting resource limitations and localised regulatory pressures. This divergence underscores the varying capacities and strategic priorities of the two organisational types.

Quantitative data indicated that 85% of large enterprises reported allocating substantial resources to ensure compliance with environmental regulations, compared to only 48% of SMEs. Large enterprises invested in advanced monitoring systems and external audits to maintain compliance, while SMEs relied on basic tools and internal reviews. These findings highlight the resource disparity between the two groups, with large enterprises better equipped to address regulatory demands comprehensively, whereas SMEs often struggle to meet even basic requirements.

The resources allocated to ensure compliance with environmental regulations. It shows that a high percentage of large enterprises (85%) dedicate substantial resources to maintain regulatory compliance, whereas less than half of SMEs (48%) allocate similar resources. This difference implies that large enterprises are better equipped to navigate complex environmental regulations and have a stronger commitment to meeting legal requirements. SMEs, often constrained by limited resources, may struggle to keep pace with evolving regulations and allocate sufficient resources to ensure full compliance.

These findings underscore the influence of organisational size on environmental accounting practices in the manufacturing sector. Large enterprises, with their greater financial resources, higher visibility, and broader stakeholder base, tend to adopt more comprehensive and proactive approaches to environmental accounting. They are more likely to invest in environmental initiatives, engage with diverse stakeholders, and prioritize regulatory compliance. Conversely, SMEs face resource constraints and may perceive less external pressure, resulting in more limited engagement with environmental accounting practices.

The research highlights the need for tailored strategies and support mechanisms to bridge the gap between large enterprises and SMEs in terms of environmental accounting. SMEs may require additional guidance, resources, and incentives to enhance their environmental accounting practices and contribute more effectively to sustainable development goals. Policymakers and industry associations can play a

crucial role in providing targeted support and promoting best practices that cater to the specific needs and constraints of SMEs in the manufacturing sector.

Qualitative insights from interviews further emphasized the role of regulatory compliance as a driver for environmental accounting. Large enterprises viewed compliance as an opportunity to demonstrate leadership in sustainability and gain a competitive edge. They often integrated regulatory requirements into broader environmental strategies. Conversely, SMEs perceived compliance as a cost burden, with limited strategic value. This perception influenced their reactive approach to environmental accounting, focusing on short-term regulatory adherence rather than long-term sustainability goals.

Document analysis revealed that large enterprises frequently disclosed detailed compliance measures in their sustainability reports, including adherence to global frameworks such as ISO 14001[6] and the Global Reporting Initiative (GRI). These disclosures enhanced transparency and accountability. SMEs, however, often provided minimal compliance-related information, reflecting challenges in documentation and reporting. This gap in regulatory transparency highlights the need for tailored support mechanisms to help SMEs improve their compliance and reporting practices.

Regression analysis demonstrated a strong positive correlation between regulatory compliance and the sophistication of environmental accounting practices in large enterprises. For SMEs, the correlation was weaker, suggesting that resource constraints and limited stakeholder pressures hinder their ability to leverage compliance as a driver for advanced practices. These findings underscore the critical role of regulatory frameworks in shaping environmental accounting, while also highlighting the disparities in how large enterprises and SMEs respond to these pressures.

5.5. Detailed policy framework and implementation strategies

Based on empirical findings, we propose specific, actionable policy interventions:

Immediate Actions (0-12 months):

1) Establish SME Environmental Accounting Support Centers in each region
- Budget: $2.3M per center annually
- Target: 500 SMEs per center per year
- Success metric: 60% improvement in basic reporting compliance

2) Launch Digital Platform Pilot Programs
- Free environmental accounting software for SMEs (<50 employees)
- Subsidized advanced features for medium enterprises (50-250 employees)
- Expected impact: 40% reduction in implementation costs

Medium-term Strategies (1-3 years):

3) Implement Tiered Tax Incentive Programs
- SMEs: 40% tax credit for system implementation (max $20K per company)
- Large enterprises: 15% tax credit for SME mentorship programs
- Projected participation: 2,500 SMEs annually

4) Create Regional Environmental Accounting Certification Programs
- Standardized curriculum across geographic regions
- Industry-specific modules for high-impact sectors
- Target: 10,000 certified professionals by 2027

6. Specific policy recommendations

Based on the empirical findings, we propose a comprehensive policy framework with specific, actionable recommendations:

6.1. Tiered regulatory framework

Recommendation 1: Size-Differentiated Reporting Requirements

Large enterprises (>250 employees): Mandatory comprehensive environmental accounting with quarterly digital submissions

Medium enterprises (50-250 employees): Simplified annual reporting with standardized digital templates

Small enterprises (<50 employees): Basic environmental impact disclosure with government-provided software tools

Implementation Timeline: 3-year phased approach with pilot programs in each geographic region

6.2. Digital platform sharing initiatives

Recommendation 2: Government-Sponsored Digital Infrastructure

Establish national environmental accounting platforms with tiered access based on organizational size

Provide free basic software for SMEs with advanced features available on a subscription basis

Create regional data-sharing networks to enable benchmarking and best practice transfer

Estimated Investment: $45M across three regions over 5 years. Expected ROI: 340% through improved compliance efficiency and reduced administrative costs

6.3. Capacity-building programs

Recommendation 3: Targeted Training and Certification

For SMEs:

Monthly webinar series on environmental accounting basics (200+ participants per session)

Online certification program with government subsidies (75% cost reduction)

Peer mentoring networks connecting SMEs with large enterprise sponsors

For Large Enterprises:

Advanced analytics and AI integration workshops
Executive leadership programs on ESG strategy
International best practice exchange programs
Budget Allocation: $12M annually across training programs

6.4. Financial incentive mechanisms

Recommendation 4: Differentiated Support Systems
Tax Incentives:
SMEs: 40% tax credit for environmental accounting system implementation
Large enterprises: 15% tax credit for supporting SME environmental accounting development
Grant Programs:
Direct funding for SME environmental accounting system implementation (up to $50K per company)
Innovation grants for large enterprises developing open-source environmental accounting tools
Procurement Preferences:
10% price preference for companies with certified environmental accounting systems
Mandatory environmental accounting requirements for government contracts >$1M

6.5. Geographic-specific strategies

Asia-Pacific Focus:
Harmonize environmental accounting standards across ASEAN countries
Establish a regional environmental accounting certification program
Create export-focused environmental accounting training for SMEs
European Focus:
Accelerate CSRD implementation support for SMEs
Develop a pan-European digital environmental accounting platform
Enhance SME access to ESG investment funding
North American Focus:
Coordinate federal-state environmental accounting standards
Establish cross-border (US-Canada) environmental accounting mutual recognition
Create sector-specific environmental accounting guidelines

7. Limitations and future research

7.1. Study limitations

This study acknowledges several important limitations that provide avenues for future research:
Geographic Scope Limitations:

- The study's focus on Asia-Pacific, Europe, and North America may not fully capture environmental accounting practices in African, Middle Eastern, and Latin American markets, where regulatory frameworks and cultural contexts differ significantly
- Within-region variations (e.g., differences between Germany and Greece in Europe) were not fully explored due to sample size constraints

Temporal Limitations:

- The 18-month data collection period (January 2022 - June 2023) preceded major regulatory changes, including full CSRD implementation and SEC climate rule finalization
- Rapid technological advancement in AI and blockchain environmental applications may have rendered some findings less current

Sectoral Focus:

- Concentration on manufacturing companies limits generalizability to service sectors, particularly emerging areas like digital services, where Scope 3 emissions from cloud computing are becoming increasingly relevant

7.2. Future research directions

Priority research areas include:
1) Longitudinal Impact Studies: 5-10 year tracking of environmental accounting evolution and financial performance correlations
2) Cross-Sectoral Analysis: Expansion to service industries, particularly fintech and digital platforms
3) Technology Integration Studies: Deep analysis of AI, blockchain, and IoT integration effectiveness
4) Cultural Context Research: Examination of how national culture dimensions influence environmental accounting adoption beyond regulatory requirements

8. Conclusion

This comprehensive analysis reveals significant disparities in environmental accounting practices between large enterprises and SMEs, with these differences moderated by geographic context and accelerated by digital transformation capabilities. The study's findings are particularly relevant given the rapid regulatory evolution of 2024-2025, including mandatory CSRD implementation and SEC climate disclosure finalization.
Key contributions to the literature include: (1) quantitative evidence demonstrating how digital transformation creates exponential advantages for large enterprises (effect size d = 2.98), (2) identification of specific geographic moderating effects that can inform targeted policy interventions, and (3) development of actionable policy frameworks with detailed implementation timelines and budget allocations.

The proposed interventions—including $47M in digital infrastructure investment and targeted SME support programs—offer evidence-based pathways for reducing the environmental accounting gap. These recommendations address both immediate compliance needs and long-term sustainability transformation, providing policymakers with concrete tools for enhancing environmental accountability across diverse organizational and geographic contexts.

The proposed tiered regulatory framework, digital platform sharing initiatives, and capacity-building programs offer practical pathways for reducing the environmental accounting gap between organizational sizes while acknowledging geographic and cultural variations. These recommendations, supported by specific budget allocations and implementation timelines, provide policymakers with concrete tools for enhancing environmental accounting adoption across diverse organizational contexts.

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