

Proactive Carbon Management in Asian Manufacturing SMEs: Insights from a Dual-Driver Case Study in Taiwan

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Abstract

This study examines why resource-constrained Asian manufacturing SMEs initiate proactive carbon management before direct regulatory enforcement and how internal strategic intent interacts with external institutional pressures. A qualitative-dominant mixed-methods case study of an export-oriented Taiwanese powder metallurgy SME combines a 2024 ISO 14064-1:2018 organizational greenhouse gas inventory with three semi-structured executive interviews. Managerial assessment preceded domestic enforcement, while customer ESG requirements, evolving carbon policy, and ISO 14064-1 provided legitimacy and an operational framework. Total 2024 emissions were 3,074.026 tCO₂e, with Scope 2 accounting for 87.40%, making energy efficiency and renewable energy the priorities of a three-phase decarbonization pathway. Interviews identified inconsistent regulatory guidance, limited supplier support, and regulatory knowledge gaps. Integrating the natural resource-based view and institutional theory, the dual-driver model shows that proactive strategic intent initiates carbon action, while institutional frameworks enable systematic and legitimate implementation. The findings qualify portrayals of Asian SMEs as passive compliance seekers, demonstrate the value of triangulating standardized inventory and managerial evidence, and identify potential spillover implications across firm, industry, and societal levels. Practically, the study highlights regulatory guidance, supplier capability development, and industry-academia collaboration as priorities for SME decarbonization support.

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1. Introduction

When the Paris Agreement established the goal of pursuing efforts to limit warming to 1.5°C in 2015, it signaled more than an environmental milestone - it marked the beginning of a fundamental shift in how carbon emissions would be governed, priced, and embedded into the global economy (IPCC, 2021). That shift accelerated in 2023, when the European Union launched its Carbon Border Adjustment Mechanism (CBAM), which entered its transitional reporting phase and began requiring EU importers of covered goods to report embedded emissions, thereby increasing carbon-data demands on their non-EU suppliers, with the definitive regime taking effect from 2026. Taiwan also announced carbon-fee rates in 2024, with implementation beginning in 2025 (Ministry of Environment, 2024), and set regulatory milestones requiring listed companies to complete greenhouse gas inventories by 2027 and third-party verification by 2029 (Financial Supervisory Commission, 2022). For export-oriented manufacturers, carbon management is increasingly becoming a core competitive capability.

For Taiwanese small and medium-sized enterprises (SMEs), however, this regulatory momentum creates a genuine paradox. These firms are small, resource-constrained, and traditionally viewed as reactive rather than proactive when it comes to environmental regulation - responding to external pressure rather than getting ahead of it (DiMaggio and Powell, 1983; Martins et al., 2022). At the same time, SMEs collectively account for a substantial share of global carbon emissions, making their role in the sustainability transition impossible to ignore (OECD, 2021). The conventional wisdom holds that SMEs facing tight resources will do the minimum required and nothing more. Yet some Taiwanese manufacturers have begun to depart from this reactive pattern by initiating carbon inventories and building carbon management capabilities before direct regulatory enforcement. This disconnect between theory and observed behavior raises a question worth taking seriously: why would a resource-constrained Asian manufacturing SME proactively adopt carbon management before direct regulatory enforcement?

Powder metallurgy offers a particularly compelling context for exploring this question. The industry serves the automotive, machinery, and electronics sectors globally, and its energy-intensive processes are increasingly scrutinized by multinational clients with stringent ESG supplier requirements (Lintukangas et al., 2023). Despite this relevance, detailed case records of carbon inventories in powder metallurgy - or in comparably specialized manufacturing SMEs - are scarce in the academic literature (Das et al., 2020). That gap, both scholarly and practical, is what this study sets out to address.

Drawing on this motivation, the study asks two related questions: How and why can proactive carbon management emerge in resource-constrained Asian manufacturing SMEs before direct regulatory enforcement takes effect? How does the interaction between a firm's internal strategic intent and its broader institutional environment shape this process? To answer them, the analysis unfolds across three dimensions. First, it traces how the case company's proactive carbon management took shape,

mapping the interplay between internal proactive environmental strategy - grounded in the Natural Resource-Based View (NRBV) - and external institutional pressures drawn from Institutional Theory, leading to the proposed dual-driver model. Second, it uses ISO 14064-1:2018 inventory data to examine the firm's emissions structure and how that structure shaped its decarbonization strategy. Third, it documents the barriers the firm encountered along the way and how it navigated them. Throughout, a case study methodology (Yin, 2018) guides the integration of quantitative inventory data and qualitative interview material.

This study contributes on three fronts. Theoretically, it moves beyond the either/or framing that dominates existing work - in which firms are explained by institutional theory or the NRBV, but rarely both - and proposes a dual-driver model in which proactive strategic intent and institutional legitimacy reinforce each other. This provides a context-specific qualification to the standard narrative of Asian SMEs as passive compliance-seekers (Das et al., 2020) and offers case-based insights into how proactive behavior can emerge. Methodologically, it pairs a two-year ISO 14064-1 inventory with semi-structured executive interviews, showing how quantitative emissions data and qualitative decision-making accounts can be systematically triangulated - a template that future researchers working on SME carbon management can adapt and build on. Practically, it gives powder metallurgy firms and similarly positioned manufacturers a documented, case-based reference for ISO 14064-1 implementation, and hands policymakers a grounded inventory of the real obstacles SMEs face when building carbon management capacity.

The paper proceeds as follows. Section 2 develops the theoretical framework, integrating NRBV, institutional theory, and the dual-driver model with a review of SME sustainability challenges, Asian carbon management practices, and ISO 14064-1. Section 3 details the research design and data collection. Section 4 reports the findings. Section 5 discusses the three analytical propositions and the spillover effects of carbon inventory action. Section 6 concludes.

2. Literature Review and Theoretical Framework

2.1 Theoretical framework: the dual-driver model

Most existing research treats institutional theory and the Natural Resource-Based View (NRBV) as alternative explanations for corporate environmental behavior, with the former emphasizing external pressure and legitimacy-seeking, and the latter focusing on internal capability development and strategic advantage. This study argues that framing misses something important. Proactive carbon management in SMEs is not driven by pressure alone, nor by strategy alone. It emerges from the intersection of both. The dual-driver model proposed here positions internal proactive environmental strategy and external institutional frameworks as complementary forces, each doing something the other cannot.

On the internal side, Hart's (1995) NRBV established that how a firm responds to its natural environment determines whether it can build sustainable competitive advantage under conditions of increasing resource constraint. Hart identified three

levels of environmental strategy capability - pollution prevention, product stewardship, and sustainable development - with each successive level requiring deeper organizational commitment and offering greater strategic differentiation. Aragón-Correa and Sharma (2003) extended this logic with the concept of proactive environmental strategy, arguing that firms treating environmental capabilities as strategic assets - rather than compliance costs - position themselves to capture first-mover advantages. More recent work has reinforced this view in export-manufacturing contexts directly relevant to this study. Mulaessa and Lin (2021) found that firms pursuing proactive environmental strategies significantly outperformed reactive counterparts on green innovation when external regulatory pressure was high. Ullah *et al.* (2024), studying export-oriented manufacturers, showed that organizational readiness for green innovation positively influenced sustainability performance through knowledge integration - confirming that getting ahead of the curve pays off in precisely the kind of setting this study examines. From an NRBV perspective, the development of systematic carbon inventory capabilities and decarbonization planning before direct regulatory enforcement may signal an emerging proactive environmental capability oriented toward sustainable development.

The external side of the model draws on DiMaggio and Powell's (1983) institutional isomorphism framework, which identifies three distinct mechanisms through which institutional environments shape organizational behavior: coercive pressures from legal and regulatory mandates, mimetic pressures from imitation of successful peers, and normative pressures from professional communities and client standards. In the context of Taiwanese export-oriented manufacturing SMEs, all three may be relevant - anticipated carbon-fee policy pressure (coercive), peer carbon disclosure practices (mimetic), and multinational client ESG procurement requirements (normative). Evidence from comparable settings supports the relevance of these pressures. Nguyen (2025), studying Vietnamese food processing firms, found that government, customer, and community pressures collectively drove green innovation through a corporate social responsibility mechanism, with government pressure exerting the strongest institutional influence - a cross-industry reference point for how institutional forces can activate proactive environmental behavior in SMEs. Suchman's (1995) legitimacy theory adds another dimension: firms that voluntarily adopt institutionally recognized environmental practices are not merely complying, they are actively pursuing moral legitimacy, strengthening trust relationships with supply chain partners, government agencies, and the broader public.

Critically, the role of institutional pressure in this framework is not to produce passive compliance. Rather, it provides the methodological legitimacy and operational structure that enables firms with existing proactive intent to act systematically. ISO 14064-1 supplies a technically credible, actionable standard. CBAM and carbon fee policies create market incentives for emissions quantification. Supply chain ESG requirements provide ongoing external validation.

Without these institutional scaffolds, a firm's proactive intent may remain strategically motivated but operationally directionless.

That is the integrative logic at the heart of the dual-driver model: institutional pressure without proactive intent produces minimum compliance and nothing more; proactive intent without an institutional framework leaves firms without an operational pathway or external verification mechanism. Utama *et al.* (2024), examining Indonesian SMEs through a tripod-based view that integrates resource-based and institution-based capabilities, found that government support and other institutional environment factors combine with firm-level resource capabilities to form a compound driver structure for strategic action - providing cross-cultural empirical support from an Asian context for the internal capability-by-external institution logic this model proposes.

2.2 SME sustainability challenges and Asian carbon management practices

SMEs occupy an uncomfortable position in the global sustainability agenda. Collectively, they contribute materially to environmental pressures, yet they are among the least equipped to respond because of persistent resource and capability constraints (Aragón-Correa *et al.*, 2008; Hillary, 2000; OECD, 2021). Martins *et al.* (2022) identified four structural barriers that consistently impede SME sustainability efforts: insufficient capital, shortage of specialist talent, information asymmetry, and fragmented managerial attention. In the specific domain of carbon management, Das *et al.* (2020) found that most Asian SMEs across multiple countries understood carbon inventory only in conceptual terms, lacking the operational capacity to translate institutional requirements into actual management practice.

What the existing literature has largely failed to capture is the other side of this story. Research has devoted considerable energy to explaining why SMEs do not act - but comparatively little to documenting how and why some do. The mechanisms that drive proactive carbon management in resource-constrained firms, and the pathways through which those firms build the necessary capabilities, remain underexplored. That gap is precisely what this study addresses. Evidence from adjacent work offers some directional guidance: Caldera *et al.* (2019) demonstrated that government subsidies, technical assistance, and institutional incentives are effective policy instruments for helping SMEs break through capability bottlenecks, while Prashar (2019) found that collaboration with external organizations can meaningfully compensate for internal resource deficits - both findings that align with the dual-driver model's emphasis on institutional frameworks as capability scaffolds.

In the Asian context, the interaction between capability constraints and institutional environment takes on particular sharpness. Carbon management research in Asia has grown rapidly in recent years, but the literature remains heavily skewed toward large firms; detailed field records of complete carbon management journeys in manufacturing SMEs are scarce (Das *et al.*, 2020). Three consistent patterns emerge

from what does exist. Supply chain pressure is the most immediate trigger for Asian SMEs to initiate carbon management - Lintukangas *et al.* (2023) demonstrated that buyer pressure in supply chains drives suppliers toward more active carbon management practices, a dynamic directly mirrored in this study's case context. Institutional environment strength significantly shapes the depth of carbon management engagement: Das *et al.*'s (2020) cross-national comparison showed that SMEs in East Asia - Taiwan, Japan, and South Korea - displayed notably higher carbon management participation under conditions of clear regulation and strong enforcement than their Southeast Asian counterparts, suggesting that Taiwan's rapidly strengthening regulatory environment is actively creating conditions for proactive SME positioning. Finally, while proactive environmental strategies remain the exception rather than the rule, they carry disproportionate influence: Prashar (2019) found that forward-looking Asian SMEs tend to generate cognitive diffusion effects within their industries, accelerating sector-wide sustainability transitions. This demonstration mechanism provides the empirical foundation for Proposition 3 of this study and connects directly back to the dual-driver model - the spillover effects generated by proactive SMEs are, in essence, the industry-level manifestation of proactive strategic intent.

2.3 Carbon inventory methodology and environmental governance significance

ISO 14064-1:2018 provides the internationally recognized framework for quantifying and reporting greenhouse gas emissions at the organizational level. Its core elements include setting organizational boundaries using the operational control approach, defining reporting boundaries across Scopes 1 through 3, collecting activity data and selecting appropriate emission factors, and applying global warming potential (GWP) values to convert emissions into CO₂ equivalents. Scope 1 covers direct emissions from stationary combustion, mobile combustion, process emissions, and fugitive releases. Scope 2 captures indirect emissions from purchased electricity and other energy sources. Scope 3 encompasses all other indirect emissions across the upstream and downstream supply chain. For manufacturing SMEs, Scope 2 energy emissions typically dominate the emissions profile and consequently become the natural starting point for short- to medium-term decarbonization strategy (Liu *et al.*, 2019; Udara Willhelm Abeydeera *et al.*, 2019). Beyond the numbers themselves, ISO 14064-1 performs a second function that is just as strategically significant: it creates a common language for carbon communication. The standardized quantification framework allows firms to exchange and verify carbon data with supply chain partners, financial institutions, and regulatory bodies on equal footing - a capability that carries particular value for Taiwanese manufacturing SMEs seeking to integrate into global supply chain carbon management systems. Prior research using a data-driven climate-risk framework shows how systematic environmental data can support enterprise risk

assessment, reinforcing the broader governance value of standardized climate information (Chiu et al., 2023).

Carbon inventory is far more than a technical accounting exercise. It is the knowledge foundation, strategic trigger, and institutional interface of climate action. What this study calls "spillover effects" refers to the chain of impacts generated when a firm-level carbon inventory action crosses organizational boundaries and propagates outward to the industry and societal levels. At the firm level, the logic is disarmingly simple: you cannot manage what you cannot measure. Systematic emissions quantification provides a basis for designing reduction pathways, tracking progress, and making credible disclosures (ISO, 2018). Liu *et al.* (2019) reinforced this point, showing that without systematic inventory, decarbonization intent rarely translates into verifiable action. Practically, a completed inventory identifies high-emission hotspots, establishes a baseline, and reveals the relative weight of each scope - giving firms the information they need to direct resources toward the highest-impact reduction opportunities first.

At the industry level, the first mover's inventory record does work that extends well beyond its own four walls. When a firm publicly discloses its emissions data, implementation process, and the barriers it encountered, it lowers the uncertainty and learning costs for peers considering similar steps, generating knowledge diffusion effects (Prashar, 2019; Lintukangas *et al.*, 2023). In industries like powder metallurgy, where documented carbon inventory cases are essentially non-existent, such a systematic and traceable record simultaneously serves as a peer reference point and a foundation for industry-level policy design.

At the societal and policy level, the cumulative effect of individual SME inventory actions builds the data infrastructure that national climate governance requires. OECD (2021) was direct on this point: without the systematic inclusion of SMEs in carbon management frameworks, national-level climate targets will remain out of reach. Manufacturing SMEs that proactively pursue carbon inventory and decarbonization strategies also contribute directly to the interconnected goals of SDG 13 (Climate Action), SDG 9 (Industry, Innovation and Infrastructure), and SDG 17 (Partnerships for the Goals).

2.4 Research gaps and analytical propositions

Three gaps in the existing literature motivate this study. First, research on carbon management among Asian SMEs has concentrated heavily on intention surveys and attitudinal measures, leaving the complete execution journey of proactive firms - inventory data, decision-making processes, and barrier navigation - largely undocumented in field-based depth. Second, organizational carbon inventory cases in specialized manufacturing sectors such as powder metallurgy are scarce in the literature, offering firms in similar positions no concrete practical reference or demonstration to draw on. Third, despite the theoretical appeal of integrating NRBV proactive environmental strategy with institutional theory, the dual-driver model

has yet to be examined through a mixed-methods design that combines quantitative carbon data with qualitative interviews in an Asian SME context.

These gaps point toward a specific kind of study that is needed: not another survey of what SMEs intend to do, but a deep field record of what one proactive firm actually did, grounded in both the numbers it produced and the decisions behind them. To guide that analysis, this study advances three propositions rather than hypotheses - consistent with the conventions of qualitative case study methodology (Yin, 2018), in which propositions serve as directional anchors for analysis rather than statements to be statistically confirmed or rejected. Each proposition maps directly onto a distinct strand of the research design: P1 corresponds to the interview module on motivational drivers, P2 to the module on implementation barriers, and P3 to the strategic analysis of quantitative inventory data - ensuring logical consistency across propositions, data collection, and analytical framework.

Table 1: The Dual-Driver Model and Analytical Propositions

Proposition	Internal Driver: Proactive Environmental Strategy	External Support: Institutional Framework	Theoretical Grounding and Research Significance
P1	The firm treats carbon management as a strategic asset, proactively initiating carbon inventory and building decarbonization capability before direct regulatory enforcement takes effect (Hart, 1995; Aragón-Correa and Sharma, 2003).	ISO 14064-1, CBAM, and supply chain ESG requirements supply a standardized pathway and legitimacy that convert proactive intent into systematic action (DiMaggio and Powell, 1983; Suchman, 1995).	Integrates Hart's (1995) NRBV with DiMaggio and Powell's (1983) institutional theory. Distinguishes the driver mechanisms of proactive environmental strategy SMEs from those of passive compliance-oriented SMEs.
P2	Resource-constrained firms face systemic barriers - inconsistent policy standards, insufficient technical support from equipment suppliers, and regulatory knowledge gaps - that limit execution of proactive intent.	Government guidance programs, industry associations, and academic collaboration provide the external capability scaffolding needed to overcome these barriers (Caldera et al., 2019; Prashar, 2019).	Engages with Caldera et al.'s (2019) policy incentive mechanisms and Prashar's (2019) external collaboration perspective; provides a field-grounded barrier inventory to inform SME carbon-management support program design.
P3	Firm-level quantification (carbon inventory) enables strategic prioritization of decarbonization actions, converting proactive intent into a ranked set of reduction priorities.	Institutional frameworks and reporting standards may facilitate the outward diffusion of firm-level actions, creating potential demonstration effects for industry peers and supporting national climate governance objectives (IPCC, 2021; OECD, 2021).	Moves the discussion beyond individual firm carbon management to connect with the broader climate governance agenda (SDG 13, 9, 17), positioning proactive SME carbon inventory as a potential source of broader environmental governance value.

Note: NRBV = Natural Resource-Based View. P1–P3 refer to the analytical propositions advanced in this study. Internal and external drivers are complementary rather than mutually exclusive.

3. Research Methodology

3.1 Research design: rationale for the case study approach

This study employs a qualitative-dominant mixed-methods case study design with quantitative support. The choice of methodology follows directly from the nature of the research questions. Yin (2018) argues that case study is the most appropriate design when research questions center on "how" and "why", when the researcher has no control over events, and when the phenomenon cannot be cleanly separated from its real-world context. All three conditions apply here: the study asks how proactive carbon management takes shape under dual-driver conditions, and why certain SMEs act before direct regulatory enforcement requires them to act. These questions are better addressed through in-depth case analysis than through surveys or experimental designs.

The decision to use a single-case rather than multi-case design rests on two grounds. First, the powder metallurgy industry represents a highly underrepresented context in Taiwan's carbon management literature; the case carries both typical and revelatory selection logic in Yin's (2018) terms - typical in that it reflects the structural conditions facing many export-oriented Taiwanese manufacturing SMEs, and revelatory in that detailed ISO 14064-1 inventory records remain scarce in the published literature on this sector. Second, the simultaneous collection of quantitative inventory data and qualitative interview material allows for triangulation across both dimensions of the dual-driver model: the inventory data documents the emissions profile generated through the standards-based inventory process, while the interview accounts expose the internal strategic intent that preceded and shaped those actions. Eisenhardt (1989) noted that case studies can combine multiple data-collection methods, enabling evidence triangulation and theory building.

Building on this design logic, the study is structured around an integrated research framework illustrated in Figure 1. Grounded in NRBV and institutional theory, the framework maps the core mechanism pathway from proactive carbon management initiation to the formation of a systematic decarbonization strategy, tracing propositions P1 through P3 and incorporating implementation barriers and resource constraints as moderating factors. This framework simultaneously guides the data collection design: quantitative inventory data supports analysis of the data-informed strategic prioritization proposed in P3, while in-depth interviews address the proactive intent and barrier navigation mechanisms of P1 and P2. The result is a structure in which research questions, theoretical propositions, and empirical data maintain logical consistency throughout.

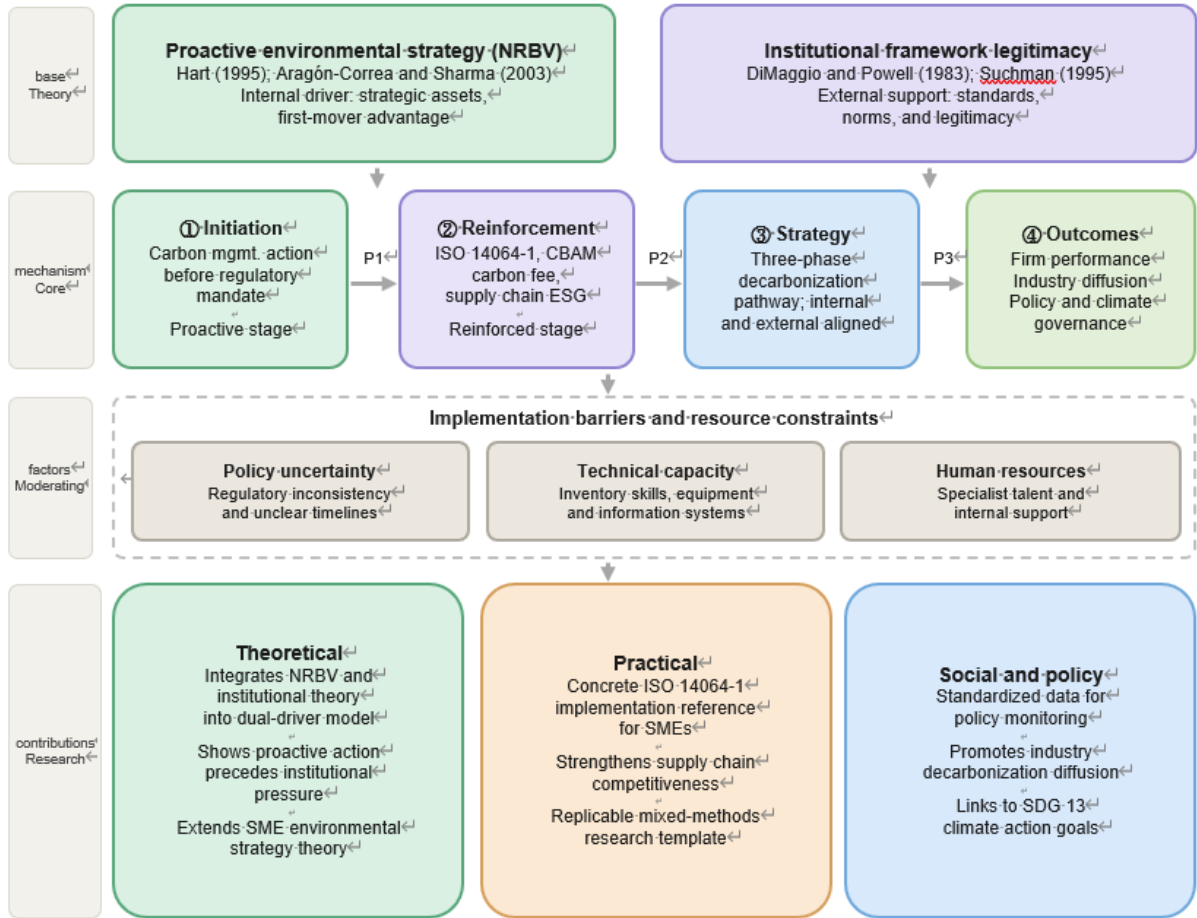


Figure 1: Research Framework of This Study

3.2 Case selection and research context

The case organization is a powder metallurgy SME headquartered in Hsinchu City, Taiwan. Founded in 1986, the company employs between 50 and 100 staff and holds registered capital of NT\$72 million, placing it firmly within Taiwan's official SME classification criteria. With over three decades of accumulated technical expertise, the firm manufactures oil-impregnated bearings, precision gears, and mechanical components for more than 500 clients across 20+ countries, making it a theoretically relevant case of an export-oriented Asian manufacturing SME.

Three characteristics make this case theoretically significant. First, the company initiated an ISO 14064-1 carbon inventory independently, before Taiwan's carbon fee policy had been formally implemented - a clear operational match for the proactive environmental strategy construct. Second, it simultaneously faces institutional pressure from two directions: normative pressure from international client ESG requirements, and anticipated regulatory pressure from Taiwan's emerging carbon fee regulations. This dual-pressure environment provides a

relevant real-world setting for examining the dual-driver model. Third, as a firm operating in a sector where documented organizational carbon inventories remain scarce, the case carries the kind of scarcity value that makes demonstration effect research possible. In keeping with research ethics, the company is anonymized throughout this study and referred to simply as "the case company."

3.3 Data collection and analysis

The quantitative component of this study consists of an organizational greenhouse gas inventory for the case company covering the 2024 fiscal year, conducted in accordance with ISO 14064-1:2018 and compared against 2023 baseline data. Organizational boundaries were defined using the operational control approach, under which 100% of greenhouse gas emissions from all facilities under the company's operational management and control are included, ensuring boundary consistency and traceability. The reporting boundary covers Scope 1 direct emissions - including stationary combustion, mobile combustion, and fugitive releases - and Scope 2 indirect emissions from purchased electricity. Scope 3 coverage is partial: given the case company's limited supply chain data collection capacity, only those "other indirect emission" categories for which data were obtainable are included; this boundary decision is addressed explicitly in the limitations section.

Emission factors follow a localization-first principle: Taiwan's Ministry of Environment published factors are applied wherever available, ensuring that calculated results align with Taiwan's regulatory reporting requirements. For emission sources without local data, default values from IPCC (2021) are used. Emissions are quantified using the emission factor method, applying the formula: activity data $\times$ emission factor $\times$ global warming potential (GWP) = CO₂-equivalent emissions. Data entry and emissions calculations were conducted using the online greenhouse gas inventory tool provided by Ministry of Environment, enhancing both computational efficiency and calculation consistency.

To capture the internal proactive strategic intent dimension of the dual-driver model, the study employs semi-structured in-depth interviews as the primary qualitative data collection method. Three key decision-makers were interviewed: the Vice General Manager (responsible for overall strategic direction), the Plant Manager (responsible for process and equipment management), and the Administrative Director (responsible for regulatory compliance and administrative resources). These three respondents were selected because their roles collectively covered the strategic, operational and administrative dimensions of the company's carbon inventory process, ensuring that the interviews captured the main decision points in its initiation and implementation. Total interview time was approximately 120 minutes. All interviews were audio-recorded with participants' informed consent, transcribed verbatim and reported using anonymized quotations.

Interview topics were structured around the two dimensions of the dual-driver model, organized into three thematic groups: Group A (motivation drivers,

corresponding to P1), covering the timing and rationale for initiating the carbon inventory, the formation of proactive awareness, and the relative influence of CBAM, carbon fee policy, and client requirements; Group B (implementation barriers, corresponding to P2), covering specific difficulties encountered during the inventory process, assessments of policy standard clarity, and gaps in equipment and personnel resources; and Group C (decarbonization strategy, corresponding to P3), covering the selection logic behind the three-phase pathway, the basis for prioritizing reduction targets, and resource allocation considerations.

Interview data were analyzed using Braun and Clarke's (2006) thematic analysis method, proceeding through data familiarization, initial code generation, theme identification, theme review, and theme naming. Member checking was conducted by returning preliminary findings to the interviewed managers for confirmation, strengthening research validity.

Research quality was ensured in accordance with the case study quality criteria recommended by Yin (2018). Construct validity was addressed through a triangulation strategy that cross-validates three data sources - quantitative inventory data, qualitative interview transcripts, and secondary documentary evidence - and through the establishment of an explicit chain of evidence ensuring that every finding can be traced back to its original source. Internal validity was maintained through the use of directional analytical propositions rather than hypothesis testing, with the theoretical framework guiding interpretation; all interview quotations are clearly attributed using anonymized respondent codes (Respondent A, B, and C) with interview context noted to prevent decontextualization. External validity is not claimed in statistical terms; the study instead pursues analytic generalization, using the case findings to enrich the theoretical propositions of the dual-driver model in ways that carry referential value for similarly positioned export-oriented manufacturing SMEs across Asia. Reliability is supported by the full preservation of inventory calculation worksheets, original interview recordings, and verbatim transcripts, which together constitute a case study database supporting the reproducibility of the research process.

4. Research Findings

The findings are organized to connect the inventory results with the three analytical propositions. Sections 4.2 and 4.3 report the emissions structure and year-on-year changes that inform strategic prioritization, while Section 4.4 presents interview evidence explaining why and how the firm acted before direct regulatory enforcement.

4.1 Case company profile

Founded in 1986 and based in Hsinchu City, Taiwan, the case company has accumulated over 38 years of manufacturing expertise in powder metallurgy. The firm specializes in the design and production of oil-impregnated bearings, precision gears, and mechanical and stainless steel components, employing between 50 and

100 staff with registered capital of NT\$72 million. Its products reach more than 500 clients across 20+ countries, making the company a theoretically relevant case within the context of export-oriented Asian manufacturing SMEs.

In terms of proactive environmental strategy context, the case company's carbon management awareness took shape before Taiwan's carbon fee policy formally came into effect. According to interview data, senior management began independently evaluating the necessity of a carbon inventory after perceiving increasingly concrete ESG requirements from international clients and recognizing the potential competitive threat posed by the EU's CBAM carbon tariff mechanism to the company's export position. ISO 14064-1 was selected as the methodological framework. The company conducted its first organizational-level greenhouse gas inventory under ISO 14064-1 in 2023, establishing a baseline emissions year, and completed its second inventory in 2024, creating the foundation for year-on-year comparative analysis.

4.2 Greenhouse gas inventory results

In accordance with ISO 14064-1:2018, the case company's total greenhouse gas emissions for 2024 were 3,074.026 tonnes CO₂e. Emissions by scope are presented in Table 2.

Table 2: 2024 Greenhouse Gas Emissions by Scope and Category

Item	Scope 1				Scope 2	Scope 3	Total emission equivalent
	Stationary combustion	Mobile combustion	Process emissions	Fugitive emissions	Energy emissions	Other indirect emissions	
GHG emissions (tCO ₂ e)	330.370				2686.909	56.746	3074.026
	2.049	7.461	0.000	320.860			
Share (%)	10.75%				87.40%	1.85%	100.00%

Note: Totals were calculated using unrounded values and may differ slightly from the sum of the displayed components.

In terms of greenhouse gas composition, CO₂ accounts for the overwhelming majority of the case company's emissions at 89.48% (2,750.773 tCO₂e). Hydrofluorocarbons (HFCs) rank second at 10.44% (320.854 tCO₂e), primarily attributable to refrigerant fugitive emissions. Methane (CH₄) and nitrous oxide (N₂O) contribute 0.04% (1.206 tCO₂e) and 0.04% (1.193 tCO₂e) respectively, together accounting for less than 0.1% of the company's total 2024 emissions of 3,074.026 tCO₂e, and are of minor significance.

These inventory results carry two important strategic implications. First, Scope 2 energy emissions account for 87.40% of total emissions in 2024, clearly establishing energy efficiency improvement and renewable energy adoption as the priority targets for short- to medium-term decarbonization. Second, although HFC fugitive emissions (10.44%) fall under Scope 1, their source - refrigerant leakage - and their remediation pathway - equipment replacement - are relatively well-defined, making them a high-certainty near-term reduction opportunity that complements the Scope 2 measures.

4.3 Contextualized year-on-year comparative analysis

To examine source-specific changes in the company's emissions, this study compares Scope 1 and Scope 2 emissions in 2024 with those in the 2023 baseline year, as presented in Table 3. Because comparable production-volume or revenue data were not available for both years, emissions intensity could not be calculated. Accordingly, this comparison should not be interpreted as a direct year-on-year emissions performance assessment, because the case company relocated to a new plant and expanded its operational scale in 2024.

Table 3: Year-on-Year Changes in Scope 1 and Scope 2 Emissions, 2023–2024

Year	Scope 1 (tCO ₂ e)	Scope 2 (tCO ₂ e)
2023 (baseline)	364.730	1,692.830
2024	330.370	2,686.909
Change	−34.360 (−9.4%)	+994.079 (+58.7%)

Scope 1 emissions decreased from 364.730 tCO₂e in 2023 to 330.370 tCO₂e in 2024, representing a reduction of approximately 9.4%. In contrast, Scope 2 emissions increased from 1,692.830 tCO₂e to 2,686.909 tCO₂e, representing an increase of approximately 58.7%. Drawing on both inventory data and interview material, three observations emerge from this year-on-year comparison.

First, plant expansion was the primary structural driver of the increase in Scope 2 emissions. The case company expanded its production scale in 2024, bringing new facilities and equipment online, which directly drove a substantial rise in purchased electricity consumption. Scope 2 energy emissions grew by approximately 58.7% between 2023 and 2024.

Second, the comparison reveals measurable progress in Scope 1 management. Stationary combustion emissions declined slightly, and HFC fugitive emissions declined following the replacement of aging refrigerant equipment, indicating that emission reduction efforts had already begun to take effect within the categories under the company's direct operational control.

Third, the comparison underscores the foundational significance of the baseline year. The company's first inventory, conducted in 2023, established the carbon emissions baseline that any credible decarbonization target-setting requires, and the 2024 increase in Scope 2 emissions driven by plant expansion further demonstrates the necessity of continuous annual inventory tracking - a recognition explicitly acknowledged by the interviewed managers.

4.4 Qualitative interview analysis: textual support for the dual-driver model

Using Braun and Clarke's (2006) thematic analysis method, three core themes were identified through theoretically guided thematic analysis from the interview transcripts, each corresponding directly to one of the study's analytical propositions: proactive awareness and institutional convergence (P1), systemic implementation barriers (P2), and the pragmatic logic of decarbonization strategy selection (P3).

Theme 1: Proactive awareness preceding regulatory enforcement (P1: supported)

All three interviewed managers consistently indicated that the company's initial motivation for pursuing a carbon inventory was not driven by any existing regulatory requirement, but by a forward-looking assessment of the competitive environment ahead. Respondent A (Vice General Manager) stated explicitly that after evaluating the potential impact of CBAM on the company's European market clients, management concluded that carbon emissions would "sooner or later become one of the conditions clients use to decide whether to continue working with us." The decision to initiate the inventory was therefore self-directed, not awaiting any government mandate.

Respondent B (Plant Manager) added a supply chain pressure dimension: some major international clients had already begun requesting carbon footprint data at the procurement enquiry stage. The recognition that "we cannot afford to have nothing ready when that moment comes" provided the internal justification for proactive action.

Theme 2: Systemic implementation barriers (P2: supported)

Despite the case company's genuine motivation to pursue carbon inventory, the interviews revealed three categories of barrier constituting systemic obstacles at the implementation level.

Barrier 1: Regulatory inconsistency. Respondent A (Vice General Manager) noted that environmental regulatory requirements vary across county and municipal jurisdictions, and that carbon inventory-related policy is "still under deliberation, with no concrete implementation guidelines yet in place." This made it difficult for the company to develop a consistent inventory plan, and the lack of clear execution standards created hesitation in resource allocation.

Barrier 2: Insufficient technical support from equipment suppliers. Respondent B (Plant Manager) pointed out that certain process equipment - such as sandblasting

machines - is not fitted with flow meters, and that the relevant equipment suppliers lack technical experience in carbon emission monitoring. The company was left to independently source alternative data, substantially increasing both the time cost and uncertainty of the inventory process.

Barrier 3: Regulatory enforcement knowledge gap. Respondent C (Administrative Director) described an instance in which an environmental engineer had requested the installation of specific monitoring equipment, only for the company to subsequently verify that the requirement was "still at the discussion stage and not yet a formally codified regulation." This exposed an information asymmetry between government enforcement agencies and firms, generating unnecessary compliance anxiety and additional administrative burden.

The co-existence of these three barrier types substantiates the systemic challenges identified in P2 and underscores the critical role of external institutional collaboration in enabling SME carbon inventory implementation.

Theme 3: The pragmatic logic of decarbonization strategy selection (P3: preliminary support)

Interview data reveal that the company's approach to decarbonization strategy is highly pragmatic and grounded in inventory data. Following confirmation that Scope 2 energy emissions accounted for 87.40% of total emissions, Respondent A (Vice General Manager) stated that "prioritizing electricity reduction has become a very clear choice," encompassing equipment upgrades and replacement, the introduction of an energy management system, and feasibility assessment for rooftop solar generation.

The respondents further explained that the three-phase progressive pathway was developed by balancing three considerations: financial feasibility, technological maturity, and certainty of emissions reduction outcomes. In the near term, priority is given to established energy efficiency measures with shorter payback periods; the medium term involves reassessing renewable energy investment; and the long term defers to the commercial maturation of carbon capture technologies. This "efficiency-first, progressive deepening" strategic logic aligns closely with P3's proposition that firm-level carbon quantification enables the strategic prioritization of decarbonization actions.

4.5 Three-phase decarbonization pathway

Drawing on the organizational carbon inventory results and interview analysis, the case company's proposed three-phase progressive decarbonization pathway is summarized in Table 4.

Table 4: Three-Phase Progressive Decarbonization Pathway of the Case Company

Phase	Timeline	Key actions	Expected decarbonization mechanism	Cumulative target
Phase 1	2025–2026	• Replace high-energy equipment with high-efficiency alternatives (LED, energy-efficient HVAC, production machinery) • Deploy energy management system (EMS) for real-time monitoring • Implement employee energy conservation training	• Direct Scope 2 reduction through improved energy efficiency • Investment in mature technologies with shorter payback periods	Near-term cumulative reduction target: 20%
Phase 2	2027–2030	• Install rooftop solar photovoltaic system • Deploy waste heat recovery equipment for process residual heat • Explore diversification of renewable energy sources	• Further Scope 2 emissions reduction through transition to renewable energy • Improved energy utilization through waste-heat recovery	Mid-term cumulative reduction target: 30%
Phase 3	2031–2050	• Apply for government low-carbon technology R&D grants • Monitor the maturity of carbon removal or carbon capture technologies • Pursue industry-academia collaboration to validate feasibility	• Reduction beyond the limits of energy-efficiency improvements • Progress toward carbon neutrality through carbon removal or carbon capture technologies	Long-term goal: Carbon neutrality

The three-phase pathway embodies a strategic logic of "efficiency first, progressive deepening." Phase 1 concentrates on deploying mature technologies with relatively predictable emissions-reduction potential and relatively predictable investment payback periods, serving simultaneously as a learning environment through which the organization builds its carbon management capabilities. Phase 2 introduces renewable energy and waste heat recovery, requiring higher upfront capital investment but advancing Scope 2 reduction from improving energy efficiency to structurally transforming energy sources. Phase 3's carbon removal or carbon capture technologies remain high-uncertainty long-term options at this stage; the pathway is accordingly designed around a cautious posture of waiting for technological maturity and using government subsidies to reduce financial risk - a pragmatic approach to emerging technology adoption that is well-suited to the resource constraints of SMEs.

5. Discussion

This section discusses the findings in four steps: the theoretical contribution of the dual-driver model, managerial implications for export-oriented Asian SMEs, policy implications for SME carbon-management support systems, and the spillover and public-value implications of carbon inventory action.

5.1 Theoretical contribution: a dual-driver explanation of proactive SME carbon management

The findings show that the case company's Vice General Manager conducted an internal strategic assessment before CBAM formally came into effect. This exhibits the temporal characteristic of proactive awareness preceding regulatory enforcement, aligning closely with the expectations of P1.

This finding enters into productive dialogue with existing literature and carries three theoretical implications. First, it enriches the literature on proactive environmental strategy among Asian SMEs. Das et al. (2020), studying SMEs across multiple Asian countries, identified reactive, compliance-driven adoption as the dominant mode, with proactive environmental strategy remaining relatively rare. The case presented here offers a context-specific counter-example. It suggests that, under conditions of high export dependence and international client ESG requirements, Asian manufacturing SMEs may move beyond passive compliance to develop a more forward-looking approach to carbon management. Aragón-Correa and Sharma (2003) argued that proactive environmental strategy is more likely to emerge when environmental uncertainty is high, and firms possess strong resource integration capabilities - the case company's three decades of accumulated technical expertise and stable international client base are precisely this condition made concrete.

Second, the findings demonstrate the integrative potential of the NRBV and institutional theory. Existing literature tends to treat institutional pressure and proactive strategy as separate explanatory frameworks corresponding to "passive compliance" and "proactive positioning" firms respectively. This study suggests that in real-world carbon management contexts, the two drivers are complementary and mutually reinforcing: the NRBV explains why firms act proactively - proactive intent supplies the direction and internal justification for action - while institutional theory explains how that intent is operationalized, with the institutional framework, most concretely ISO 14064-1, providing the pathway that converts intent into verifiable organizational action.

Third, the study contributes a three-level analytical framework - firm, industry, and societal - that extends the prevailing firm-centered treatment of carbon management benefits in the existing literature. Future research could also examine the boundary conditions of the "intent $\times$ institutional convergence" effect in larger samples of Asian SMEs.

5.2 Managerial implications for export-oriented Asian SMEs

For managers, the central lesson of the case is that a carbon inventory functions not as a compliance exercise but as a strategic diagnostic tool. The inventory results directly guided the strategic focus of the three-phase decarbonization pathway: Scope 2's 87.40% share determined the priority ordering of energy efficiency and renewable energy investment, while the identification of HFC fugitive emissions at 10.44% established a near-term, high-certainty reduction opportunity through improved refrigerant management. This emphasis on energy efficiency is also consistent with recent industrial evidence showing that energy-aware predictive maintenance can link equipment monitoring to measurable gains in equipment efficiency and reductions in carbon intensity (Chiu et al., 2026). This logical sequence, moving from quantification to identification and then to strategy, resonates with the IPCC's (2021) emphasis on precise emissions quantification as a prerequisite for effective climate action and aligns with Hart's (1995) NRBV capability-building pathway from pollution prevention through knowledge accumulation to competitive advantage. For similarly positioned export-oriented SMEs, the implication is concrete: an ISO 14064-1 inventory converts diffuse decarbonization pressure into a ranked list of actionable priorities, allowing limited resources to be concentrated where the potential for emissions reduction is greatest.

5.3 Policy implications for SME carbon-management support systems

The findings not only support the three categories of systemic barrier anticipated by P2, but reveal a common structural root underlying all three: Taiwan's carbon management policy ecosystem remains in the early stages of rapid institutionalization, and the supporting infrastructure of regulatory standards, technical specifications, and market capabilities has yet to mature in tandem.

This structural diagnosis engages directly with Caldera et al.'s (2019) policy incentive research, which demonstrated that subsidies and technical assistance are generally more effective than direct regulatory mandates in helping SMEs overcome sustainability transition barriers. The barrier inventory produced by this study provides a concrete policy intervention map: addressing "regulatory inconsistency" requires cross-ministerial legal integration and clear implementation guidelines; resolving "insufficient technical support from equipment suppliers" requires government programs to help equipment vendors build carbon inventory instrumentation service capabilities; and closing the "regulatory enforcement knowledge gap" requires standardized communication mechanisms among environmental engineers, firms, and regulatory authorities. Prashar (2019) emphasized the importance of external collaboration in helping Asian SMEs overcome capability bottlenecks, and the case company did indeed rely on methodological guidance from external academic consultants during the inventory process. This SME-academia collaboration model warrants systematic incorporation into policy design - for instance, through industry-academia grant programs that encourage university research teams to assist SMEs in conducting their first carbon inventory, thereby lowering the entry barrier.

5.4 Carbon-inventory spillover and public-value implications

Beyond the firm itself, the findings indicate the potential environmental governance spillover implications proposed in P3 at the industry and societal levels.

At the industry level, the case may function as a demonstration record. As a rare documented ISO 14064-1 inventory case in Taiwan's powder metallurgy sector, the inventory methodology, emissions data, and implementation barrier records documented in this study carry potential demonstration and knowledge-diffusion value for industry peers. Lintukangas et al. (2023) showed that firms actively engaging in supply chain carbon management generate diffusion effects within their industries, accelerating sector-wide capability-building; the in-depth case record produced by this study provides a case-based illustration of this mechanism in Taiwan's specialized manufacturing context.

At the societal and policy level, the case inventory data constitute first-hand field records of organizational carbon emissions from a Taiwanese manufacturing SME. When combined with broader evidence, these data may inform government analysis related to carbon fee rate-setting, sector-specific reduction benchmark design, and the design of targeted SME capacity support programs. OECD (2021) identified data gaps as one of the most significant obstacles governments face in formulating effective SME sustainability policies; the detailed inventory record this study provides represents a potential contribution to closing that policy information gap. Table 5 summarizes these multi-level governance effects.

Table 5: Multi-Level Governance Implications of Carbon Inventory: From Firm Capability to Institutional Diffusion

Level	Core mechanism and environmental significance	Case evidence	Key references
Firm level	Carbon data quantification enables environmental capability building, allowing firms to identify high-emission hotspots and focus their strategic efforts.	Scope 2's 87.40% share of reported 2024 emissions establishes the priority governance target for the three-phase decarbonization pathway.	IPCC (2021); Liu et al. (2019)
Industry level	Demonstration effects and knowledge diffusion lower the cognitive and operational costs of carbon inventory adoption for industry peers.	The documented ISO 14064-1 case in Taiwan's powder metallurgy sector offers potential replication and benchmarking value for the industry.	Prashar (2019); Lintukangas et al. (2023)
Societal and policy level	The accumulation of SME carbon data forms institutional infrastructure supporting policymaking and climate governance.	Firm-level inventory data contribute to supply chain carbon transparency and support progress toward Taiwan's 2050 net-zero target.	OECD (2021); IPCC (2021)

P1–P3 refer to the analytical propositions advanced in this study. In this study, spillover effects are understood as the potential chain of impacts through which firm-level carbon inventory action crosses organizational boundaries and may propagate to the industry and societal levels. Taken together, the proposition advanced in P3 - that proactive SME carbon inventory can generate public-value implications - receives preliminary case-based support. A single firm-level voluntary inventory action, through knowledge spillover and the supply of policy-relevant information, may generate environmental governance implications extending beyond organizational boundaries and may constitute a concrete micro-level node of action in the realization of SDG 13 (Climate Action) and SDG 17 (Partnerships for the Goals).

6. Conclusion

This study proposed and examined a dual-driver model integrating Hart's (1995) natural resource-based view with DiMaggio and Powell's (1983) institutional theory, using a powder metallurgy SME in Taiwan to provide case-based insights into how proactive environmental strategic intent and external institutional frameworks jointly shape organizational carbon inventory implementation, and to identify its potential implications at the firm, industry, and societal levels.

The study contributes in three ways. Theoretically, the dual-driver model offers a case-grounded, more integrated analytical lens for examining proactive carbon management among Asian SMEs than single-framework approaches, treating the NRBV and institutional theory as complementary rather than mutually exclusive; the three-level spillover framework identifies potential links between firm-level action, industry diffusion, and societal climate governance; and the case provides a context-specific example of proactive SME behavior that contrasts with the passive adoption pattern identified by Das et al. (2020). Methodologically, the study offers an adaptable case-study approach that triangulates an ISO 14064-1 organizational inventory with semi-structured executive interviews, capturing emissions structure and decision-making processes simultaneously. Practically, it delivers a detailed operational record of ISO 14064-1 implementation in a resource-constrained SME, a data-driven three-phase decarbonization pathway following a sequence from quantification through identification to strategic focus, and field-grounded policy recommendations for SME carbon support programs.

Four limitations suggest corresponding directions for future research. The single-case design pursues analytic rather than statistical generalization; multi-case comparative research could examine the boundary conditions of the dual-driver model across industry contexts, firm sizes, and degrees of internationalization. Scope 3 coverage remains partial owing to supply chain data constraints; as regulatory requirements for supply chain disclosure expand, future studies can incorporate broader Scope 3 data. Interviews were confined to decision-level personnel; multi-level interview designs could capture frontline implementation perspectives. Finally, the study has not yet evaluated the implementation outcomes

of the proposed pathway longitudinally; longitudinal follow-up upon completion of Phase 1 (2025–2026) could assess the practical applicability of the "efficiency-first, progressive deepening" strategic logic, while research on managerial environmental cognition could deepen the model at the individual level.

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