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Circular Economy Practices and Firm Financial Performance: Empirical Evidence from FMCG Companies in Southeast Asia

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ABSTRACT

This article examines how circular economy practices influence financial performance and market valuation among fast-moving consumer goods (FMCG) companies in Southeast Asia. It focuses on two operationally consequential dimensions: waste-management practices and compliance with green regulation. These dimensions are considered alongside resource efficiency, circular product and packaging design, reverse logistics, and the quality of environmental disclosure. The study develops an accounting-oriented framework that connects circularity to cost of goods sold, operating expenses, working-capital requirements, capital expenditure, risk exposure, brand reputation, and investors' assessment of future cash flows. The article adopts a structured evidence-synthesis approach, drawing on peer-reviewed studies published from 2021 onward and authoritative regional and global reports. The synthesis indicates that circular practices are not uniformly or immediately profitable: waste prevention and material efficiency can produce relatively direct cost savings, whereas redesign, collection infrastructure, recycled-content procurement, and compliance systems may impose substantial up-front costs and uncertain payback periods. Financial benefits are more likely when circular initiatives are embedded in operating routines, supported by reliable measurement, and aligned with product economics and supply-chain capabilities. Regulatory compliance can reduce expected penalties and transition risk, but disclosure alone does not establish operational circularity. For market value, credible, comparable, and financially material evidence is more persuasive than broad sustainability claims. Because no harmonized firm-year dataset is supplied or newly estimated in this manuscript, the article does not report invented regression coefficients or claim original causal estimates. Instead, it consolidates available empirical evidence and specifies a transparent panel-data design for testing these relationships in Southeast Asian FMCG companies. The framework offers implications for management accounting, capital allocation, investor communication, and future empirical research.

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1. INTRODUCTION

The fast-moving consumer goods sector occupies a distinctive position in the transition from linear production to a circular economy. FMCG firms sell products that are purchased frequently, have relatively short use cycles, and often depend on extensive packaging, agricultural or petrochemical inputs, high-volume distribution, and complex retail relationships. These characteristics make resource productivity commercially important while also creating substantial waste streams. Packaging may be necessary to preserve product safety, hygiene, shelf life, and transport efficiency, yet its short service life can leave firms exposed to growing scrutiny over plastic pollution, material recovery, and end-of-life responsibility. Circularity is therefore not simply an environmental add-on for FMCG companies; it is increasingly connected to product design, procurement, manufacturing, logistics, brand management, and the economics of growth (OECD, 2022; Phattanaviroj & Pattaradej, 2025; UNEP, 2023).

Southeast Asia is an especially relevant setting for examining these tensions. The region combines fast-growing consumer markets, urbanization, export-oriented manufacturing, uneven waste-management infrastructure, and substantial variation in regulatory capacity. FMCG businesses operate across jurisdictions in which packaging rules, extended producer responsibility (EPR), recycling systems, environmental disclosure requirements, and enforcement mechanisms differ in scope and maturity. Regional firms may therefore face a dual challenge: they must respond to changing stakeholder expectations and regulation while

operating in supply chains where collection, sorting, recycling, and high-quality recycled material are not always available at scale. The economic consequences of circularity are likely to depend not only on a company's stated ambition but also on the institutional conditions in which its operations are embedded (ASEAN, 2021; OECD, 2022; World Bank, 2021).

For finance and accounting, the central question is not whether circularity is normatively desirable, but under what conditions it changes the firm's cash flows, risk profile, capital requirements, and market valuation. Waste prevention can lower material purchases, disposal fees, and production losses. Reuse systems may reduce packaging expenditure over repeated cycles but require reverse logistics, cleaning, tracking, and consumer participation. Recycled-content packaging may reduce dependence on virgin materials while increasing input-price volatility or creating quality-control costs. Investments in redesign, refill systems, recovery infrastructure, and traceability may also affect depreciation, working capital, and the timing of recognized expenses. Consequently, a firm can improve environmental indicators while experiencing short-run pressure on margins, or it can generate cost savings without achieving a meaningful reduction in absolute material throughput. Financial analysis must distinguish these outcomes rather than treating all circular initiatives as equivalent (Gonçalves et al., 2022; Kanzari et al., 2022; Antonioli et al., 2022).

The empirical literature has advanced, but important uncertainties remain. Studies have reported positive relationships between circular economy practices and performance, including through environmental improvement, innovation, brand reputation, and sustainable supply-chain management. Other work emphasizes implementation costs, measurement limitations, firm-size differences, and the need to assess performance over a sufficiently long horizon. Meta-analytic evidence suggests that circular practices can support business and environmental outcomes, while also showing that sector, country, and firm characteristics shape the magnitude of observed effects (Yu et al., 2022; Rodríguez-González et al., 2022; Pan et al., 2024; Magnano et al., 2024). Yet broad manufacturing samples cannot automatically be generalized to FMCG companies, where product turnover is high, packaging is central, brand reputation is commercially salient, and regulatory exposure can vary across countries and product categories.

A second gap concerns the treatment of financial performance itself. Many studies rely on survey perceptions or composite performance scales. Such measures are useful for examining managerial mechanisms but are not interchangeable with audited accounting outcomes or market-based indicators. Return on assets (ROA), return on sales (ROS), operating margin, asset turnover, Tobin's Q, and market-to-book ratios capture different aspects of financial value. A circular initiative may improve operating efficiency but require capital investment that depresses short-run ROA. Investors may reward a credible reduction in transition risk before it becomes visible in annual earnings, or they may discount sustainability claims that are weakly linked to cash-flow prospects. An accounting-oriented framework must therefore separate operating outcomes from capital-market outcomes and specify the channels through which each is expected to change (Kanzari et al., 2022; Nosková et al., 2024).

A third gap is regional and regulatory. Much of the firm-level evidence comes from Europe or China, while Southeast Asian FMCG companies face a more heterogeneous combination of infrastructure, regulatory enforcement, consumer purchasing power, and disclosure practices. The region is not a single institutional environment. A multinational with standardized sustainability systems may have different capabilities and reporting incentives from a domestic producer that depends on informal collection networks or faces limited access to recycled feedstock. Cross-country variation can be analytically useful, but only if country institutions are measured rather than treated as background noise. The relationship between circularity and performance should be expected to vary with regulatory credibility, waste infrastructure, firm scale, and the maturity of supply-chain partnerships (OECD, 2022; UNEP, 2023; World Bank, 2021).

This article addresses these gaps by synthesizing recent empirical evidence and developing a firm-level research framework for FMCG companies listed or operating in Southeast Asia. It concentrates on waste management and green regulatory compliance as two observable, decision-relevant dimensions of circular economy implementation. It also considers circular packaging and product design, material efficiency, reverse logistics, and environmental accounting as mechanisms that can strengthen or weaken the financial effects. The analysis is guided by three questions: (1) through what accounting and managerial channels can

circular economy practices affect profitability and operating efficiency? (2) when might waste management and green regulatory compliance be associated with higher market valuation? and (3) how should researchers test these relationships in a heterogeneous Southeast Asian FMCG setting without confusing disclosure quality with actual circular performance?

The article makes three contributions. First, it connects circular economy research to financial accounting by identifying the income-statement, balance-sheet, cash-flow, and risk channels through which initiatives can affect firm value. Second, it distinguishes waste-management performance from regulatory compliance, treating the former as an operational capability and the latter as a combination of legal risk management and institutional legitimacy. Third, it proposes a transparent panel-data design that can be implemented with audited financial statements, annual reports, sustainability disclosures, and market data. The manuscript is evidence-based but does not claim to have estimated an original Southeast Asian company panel. This distinction is important: a credible research article should not manufacture observations, coefficients, or significance tests when the underlying dataset has not been assembled and analyzed.

The remainder of the article proceeds as follows. Section 2 reviews the conceptual and empirical literature and develops hypotheses. Section 3 outlines a replicable research design, variable operationalization, and estimation strategy. Section 4 presents an evidence-synthesis analysis of the mechanisms and boundary conditions documented in recent research, followed by implications for the proposed empirical tests. Section 5 discusses managerial and accounting implications, limitations, and directions for future work. Section 6 concludes.

2. LITERATURE REVIEW

2.1 Defining circular economy practices at the firm level

Circular economy is best understood as a set of principles and operating models intended to retain the value of products, components, and materials for longer while reducing waste and dependence on virgin resource extraction. At firm level, the concept covers several distinct activities: preventing waste at source, reducing material intensity, designing products and packaging for durability or recovery, reusing products or containers, recycling materials, recovering value from residuals, and developing reverse flows that reconnect post-consumption materials with production. These activities differ in their environmental consequences and cost structures. Waste prevention avoids resource use before it occurs, whereas recycling manages materials after use and may involve collection, sorting, transport, contamination, and processing losses. For this reason, a single binary measure of "circular adoption" can obscure important differences between prevention, recovery, and end-of-pipe treatment (Ellen MacArthur Foundation, 2021; OECD, 2022; Magnano et al., 2024).

For FMCG companies, circularity frequently centers on packaging and production residues. Relevant actions include lightweighting, eliminating unnecessary components, using reusable transport packaging, increasing recycled content, developing refill or return systems, reducing food and ingredient losses, improving water and energy efficiency, and partnering with recyclers and retailers. Each intervention has a different cost-benefit profile. Lightweighting may reduce material consumption and freight costs relatively quickly, but it must not compromise product protection. Recycled-content packaging can reduce demand for virgin resin but depends on food-contact standards, material quality, and supply availability. Refill models can reduce single-use packaging but require changes in consumer behavior, distribution design, cleaning protocols, and store operations. Thus, the financial impact should be assessed at the level of the specific intervention and the product system in which it is deployed (OECD, 2022; UNEP, 2023).

The circular economy should also be distinguished from a narrow recycling agenda. Recycling rates can rise while absolute material use continues to grow, and waste can be diverted from landfill without reducing the volume of packaging placed on the market. A firm may report that a package is technically recyclable even where local collection and processing systems cannot recover it. Similarly, a recycled-content claim may reflect a small product line rather than a material shift in the firm's portfolio. Operationally meaningful circularity therefore requires metrics that connect inputs, product design, waste generation, recovery, and actual material flows. From a management-accounting perspective, the unit of analysis should be sufficiently

precise to reveal whether a project creates cost savings, shifts costs elsewhere in the value chain, or merely improves a reporting metric (OECD, 2022; UNEP, 2023; GRI, 2021).

2.2 Natural-resource-based view

The natural-resource-based view (NRBV) extends the resource-based logic of competitive advantage by emphasizing organizational capabilities related to pollution prevention, product stewardship, and sustainable development. The central implication is that environmental action can become economically valuable when it is embedded in routines that competitors cannot quickly replicate. Pollution prevention can reduce waste and input costs; product stewardship can improve coordination across product life cycles; and sustainable development capabilities can support innovation and resilience under changing environmental constraints. In FMCG, such capabilities may be reflected in cross-functional packaging redesign, supplier qualification for recycled materials, process-control systems that prevent spoilage, and reverse logistics partnerships. The NRBV predicts that circular practices will be more financially consequential when they become operating capabilities rather than isolated compliance projects (Pan et al., 2024; Magnano et al., 2024).

The NRBV also clarifies why the same environmental practice can produce different results across firms. A company with procurement expertise, product-development capacity, supplier data, and stable retailer relationships may be able to reduce material use without compromising quality. A less capable firm may face higher unit costs, operational disruption, or inconsistent recycled-material supply. Environmental initiatives are therefore not automatically strategic resources; their value depends on complementary capabilities, learning, and execution. This distinction supports the expectation that circular practices have heterogeneous financial effects and that firm size, innovation capability, and supply-chain integration should be considered in empirical models.

2.3 Stakeholder theory and legitimacy

Stakeholder theory proposes that organizational outcomes depend partly on how firms manage relationships with parties that can affect or are affected by business activity. For FMCG firms, stakeholders include consumers, retailers, suppliers, employees, regulators, communities, lenders, and institutional investors. Waste and packaging are highly visible issues, so circular practices may influence brand trust, retailer access, employee engagement, and investor perceptions. However, stakeholder responses depend on credibility. Claims that are not supported by measurable outcomes can invite accusations of greenwashing and damage legitimacy. Environmental reporting can reduce information asymmetry, but its value is limited when indicators are not comparable, boundaries are unclear, or disclosures emphasize intentions instead of performance (GRI, 2021; IFRS Foundation, 2023; Magnano et al., 2024).

Legitimacy theory is particularly relevant to regulatory compliance. Companies may adopt environmental systems partly to maintain a social license to operate and signal that their activities conform to prevailing norms. Compliance can protect the firm from sanctions and disruption, but formal conformity does not necessarily demonstrate that circular outcomes are improving. The framework therefore separates compliance as a risk-management mechanism from waste performance as an operational outcome. The two may reinforce one another, yet they should be measured separately to avoid interpreting the existence of a policy or certification as evidence of reduced waste.

2.4 Institutional theory and regulatory pressure

Institutional theory explains how rules, enforcement, professional norms, and imitation shape organizational practices. Environmental regulation can influence circularity through mandatory packaging requirements, producer responsibility obligations, waste-handling rules, disclosure standards, and penalties for non-compliance. The financial effect depends on the credibility and predictability of these rules. Stronger enforcement can make investment in compliant processes economically rational by raising the expected cost of inaction. Conversely, uncertain or uneven enforcement may encourage symbolic compliance or delay investment. In Southeast Asia, regulatory heterogeneity offers a useful setting for testing whether the financial implications of circularity vary with institutional pressure, but country-level legal frameworks must

be coded with care because a regulation's announcement, implementation, enforcement, and coverage are not equivalent events (ASEAN, 2021; OECD, 2022; World Bank, 2021).

Institutional pressure may also create a cost disadvantage in the short term. A company that invests early in compliant packaging, traceability, or recovery systems can incur costs before infrastructure and consumer practices mature. Yet early investment may reduce future transition costs and strengthen relationships with regulators and retail customers. The net effect depends on timing, the quality of implementation, and whether the firm can translate compliance into operational efficiency or market differentiation. Accordingly, regulation should be modeled not only as a direct predictor but also as a contextual factor that can change the payoff to circular capabilities.

2.5 Signaling theory and market valuation

Market valuation reflects investors' expectations about future cash flows, risk, and the quality of information available to price those expectations. Circularity may be relevant to valuation when it signals lower exposure to waste liabilities, regulatory penalties, supply disruptions, and future packaging redesign costs. It may also signal innovation capability and the ability to adapt products to changing consumer and retailer preferences. Yet signals are informative only when they are credible and difficult to imitate through inexpensive rhetoric. Quantified waste-intensity trends, verified compliance, capital expenditure linked to measurable outcomes, and transparent reporting boundaries can provide stronger signals than broad statements of environmental ambition. This logic implies that market effects may depend on disclosure quality and external assurance, while operational circularity remains the underlying activity that should ultimately support the signal (IFRS Foundation, 2023; Kanzari et al., 2022; Quaser, 2026).

2.6 Waste management and financial performance

Waste management can affect profitability through several channels. First, prevention and process optimization reduce the purchase of materials that do not become saleable output. Second, improved yield can reduce rework, spoilage, downtime, and disposal costs. Third, recovery or reuse can create secondary material value or reduce the cost of packaging and transport assets. Fourth, more reliable waste data can help managers identify loss points and compare facilities. These benefits are consistent with the argument that circular practices can improve commercial performance, although their magnitude depends on implementation and measurement (Yu et al., 2022; Rodríguez-González et al., 2022; Pan et al., 2024).

The financial pathway is not limited to direct savings. A well-designed waste-management program may improve supplier coordination, operational resilience, and brand reputation. For instance, preventing production losses can improve capacity utilization, while credible packaging recovery can strengthen retailer relationships and reduce reputational exposure. Empirical research has found that waste treatment and recycling can be associated with financial performance through reputation, while waste reduction may have a more direct cost channel (Mazzucchelli et al., 2022). This distinction is relevant for FMCG firms because consumer-facing brands may benefit from reputational effects, but the effect will differ across categories and markets. Products purchased mainly on price may not command a premium for circular packaging, while brands with stronger consumer engagement may be better positioned to convert credible environmental performance into demand or retailer support.

Nevertheless, waste-management metrics require caution. A high recycling rate can coexist with high total waste generation, and a reduction in waste per unit may be offset by sales growth. Relative indicators are useful for efficiency analysis but should be paired with absolute indicators to assess total impact. The financial consequences should also be separated from environmental outcomes: a waste contractor may reduce reported landfill disposal without materially changing product design or material intensity. A robust study should therefore measure waste generated, waste intensity, recovery rate, hazardous waste where relevant, and the quality of evidence supporting each measure. Where firms do not report comparable data, missingness should be recorded rather than silently interpreted as poor performance.

Based on these arguments, the first hypothesis is formulated as follows: **H1:** stronger waste-management performance is positively associated with accounting-based financial performance among Southeast Asian FMCG companies. The hypothesis concerns operational performance rather than the mere presence of a waste policy. The expected positive relationship is most plausible when prevention, yield

improvement, and recovery reduce recurring costs enough to offset implementation expenses. The relationship may be weaker in the early stages of capital-intensive circular projects or where recovery infrastructure is unreliable.

2.7 Green regulatory compliance and financial performance

Green regulatory compliance can affect financial performance by lowering expected legal penalties, avoiding production interruptions, reducing the likelihood of product withdrawal, and improving the predictability of investment planning. Compliance systems can also force firms to collect better environmental data and formalize responsibilities across plants and suppliers. Where regulatory requirements are stable and enforced, firms that build compliance into operations may avoid the repeated costs associated with reactive adjustments. Compliance can thus function as a form of risk control rather than simply an administrative expense (OECD, 2022; IFRS Foundation, 2023).

However, compliance is not necessarily synonymous with superior profitability. Environmental rules may require capital expenditure, testing, supplier changes, reporting infrastructure, or redesign of packaging. Those costs can be material for firms with thin margins or limited access to technology. Benefits may arrive later, especially where the main gain is reduced exposure to future penalties or avoided transition costs. Compliance can also be a minimum threshold: once most competitors satisfy a rule, it may no longer create differentiation. Therefore, the financial effect may be positive over a longer horizon but ambiguous in the short run. A static model that assumes immediate returns risks overlooking the timing of regulatory costs and benefits.

Compliance quality also varies. A company can have a formal environmental management system while experiencing repeated violations, or it may report compliance without disclosing the scope of its operations. In empirical analysis, a compliance index should distinguish legal requirements, reported incidents, penalties, certifications, and the completeness of disclosure. Regulatory pressure can be coded at the country-year level, but firm-level compliance should capture whether the company actually meets relevant requirements. Combining these into one index would blur the difference between the strength of external pressure and the firm's response to that pressure.

H2: stronger green regulatory compliance is positively associated with accounting-based financial performance among Southeast Asian FMCG companies. This expectation reflects lower expected losses and more disciplined operations, not the claim that every compliance expenditure yields an immediate accounting return. The empirical model should test lagged effects and allow for nonlinearities, particularly when compliance investment is high relative to the firm's operating scale.

2.8 Circular economy practices and market valuation

Market-based performance differs from accounting performance because it incorporates forward-looking expectations. If investors believe circular capabilities reduce future liabilities, strengthen customer loyalty, or improve resilience to material-price shocks, the firm may receive a valuation premium before the full effect appears in earnings. Conversely, investors may discount a firm whose circular commitments require substantial capital expenditure but whose business case is unclear. The literature on financial outcomes of circular business models emphasizes that financial assessment should be aligned with the transition stage and should distinguish prospective from retrospective evaluation (Kanzari et al., 2022). Long-horizon projects may look unattractive when assessed only through one-year accounting ratios, while market value can change as investors revise expectations about future cash flows and risk.

Waste-management performance may affect valuation through the credibility of operational capability and the expected persistence of cost savings. A firm that demonstrates a multi-year decline in waste intensity, absolute waste reduction, and stable or improving margins offers a stronger signal than a firm that reports a single recycling milestone without contextual data. The signal is particularly relevant in FMCG because packaging controversies can escalate quickly into consumer, retailer, or regulatory pressure. Nonetheless, the market may respond differently across firms depending on analyst coverage, ownership structure, liquidity, and investor attention to environmental risks, and recent evidence suggests that corporate governance conditions how investors value environmental accounting disclosure (Mustofa et al., 2026).

Market valuation should therefore be treated as a separate dependent variable and tested with firm and year effects where data permit.

H3: stronger waste-management performance is positively associated with market valuation among Southeast Asian FMCG companies. **H4:** stronger green regulatory compliance is positively associated with market valuation. Both hypotheses imply that the market rewards credible reductions in expected risk and improvements in future cash-flow prospects. They do not imply that investors automatically reward sustainability language or that the market fully prices environmental information in every country and period.

2.9 Mediating mechanisms: cost efficiency, reputation, and risk

The relationship between circularity and financial performance is unlikely to be entirely direct. Cost efficiency is one mediator. Waste prevention and material redesign may reduce input costs, improve yields, lower waste-treatment charges, and release capacity. These effects should appear in gross margin, operating margin, or asset turnover, although accounting classifications can differ across firms. A firm may classify waste-handling costs within cost of goods sold, manufacturing overhead, selling expenses, or other operating expenses, which complicates cross-company comparisons. Management accounting systems should therefore map circular initiatives to relevant cost centers and avoid relying exclusively on high-level ratios.

Brand and stakeholder reputation is a second mediator. Circular packaging and waste programs can help protect brand legitimacy, especially when environmental claims are visible to consumers and retailers. However, reputational benefits require credible evidence and may not translate into price premiums in every category. In price-sensitive markets, consumers may express support for sustainability but continue to choose lower-priced alternatives. Reputation may also operate defensively: the benefit is an avoided loss of trust rather than a measurable sales increase. This suggests that studies should consider both positive revenue effects and avoided downside risk, while acknowledging that the latter is difficult to observe directly.

Risk reduction is a third mediator. Compliance can lower expected penalties and the probability of costly operational disruption. Circular sourcing can also diversify material supply, although reliance on recycled feedstock may create new risks related to quality, contamination, and availability. Firms should therefore evaluate risk on a portfolio basis rather than assuming that circular inputs are inherently less risky. Financial statements may not separately disclose environmental contingent liabilities or expected regulatory costs, so researchers may need to supplement accounting data with reported incidents, enforcement notices, and risk disclosures.

H5: the positive association between circular economy practices and accounting-based performance is partly mediated by cost efficiency. **H6:** the positive association between circular economy practices and market valuation is partly mediated by credible environmental reputation and lower perceived transition risk. These hypotheses distinguish the operational pathways from the external evaluation of those pathways. Mediation tests require temporal ordering and should not be interpreted causally when the design relies solely on contemporaneous observational data.

2.10 Moderating effects: firm size, digital measurement, and institutional context

Firm size may moderate the financial returns to circularity. Large firms can spread fixed costs of measurement systems, supplier audits, packaging research, and recovery partnerships across higher sales volumes. They may also have stronger bargaining power with packaging suppliers and retailers. At the same time, large firms have more complex portfolios and can face substantial legacy costs when changing packaging specifications across markets. Smaller firms may be more agile but lack access to financing, technical expertise, and stable recycled-material supplies. Firm size should therefore be treated as a potential moderator rather than assumed to have a uniformly positive effect.

Digital measurement capabilities can improve the quality of circular decision-making. Product-level material data, manufacturing sensors, traceability systems, and integrated enterprise systems can help firms connect waste quantities to production volumes, product specifications, and cost centers. Yet digital tools do not create value automatically. Poor data governance, inconsistent definitions, or disconnected reporting systems can produce dashboards that are visually sophisticated but operationally unhelpful. Digital

measurement should be conceptualized as a complementary capability that increases the reliability and decision-usefulness of circular metrics, rather than as a substitute for physical waste reduction.

Institutional context is also likely to matter. A credible regulatory regime can increase the cost of non-compliance and reward early adaptation, whereas weak enforcement may reduce the immediate financial incentive to invest. Waste infrastructure influences whether recyclable materials can be collected and processed, and consumer purchasing power affects the commercial feasibility of refill or return models. Cross-country models should therefore include country-year regulatory indicators and, where possible, measures of waste infrastructure and recycling capacity. Because Southeast Asian countries differ in market size, development level, and regulatory design, country comparisons should avoid simplistic rankings that ignore implementation details.

H7: firm size moderates the relationship between circular economy practices and financial performance. **H8:** stronger environmental data and measurement capability strengthens the relationship between circular practices and financial performance. H9: the positive association between circular practices and financial performance is stronger where regulatory enforcement and recovery infrastructure are more developed. These are conditional hypotheses; the direction and magnitude of some interactions may differ across specific circular practices and FMCG subsectors.

2.11 Conceptual model

The proposed model treats waste-management performance and green regulatory compliance as the primary explanatory variables. Circular design, material efficiency, and reverse logistics can be modeled as complementary dimensions or robustness variables. Accounting performance is represented by ROA, operating margin, and ROE where comparable; market valuation is represented by Tobin's Q or market-to-book ratio. Cost efficiency, environmental reputation, and perceived transition risk are potential mediators. Firm size, digital measurement capability, regulatory enforcement, and waste infrastructure are potential moderators. Firm leverage, sales growth, capital intensity, firm age, subsector, ownership, and country-year conditions are included as controls. The model is intentionally multidimensional: no single indicator can capture all financial and environmental effects of circularity.

Table 1. Summary of hypotheses

Hypothesis	Proposed relationship	Expected sign
H1	Waste-management performance → accounting performance	+
H2	Green regulatory compliance → accounting performance	+
H3	Waste-management performance → market valuation	+
H4	Green regulatory compliance → market valuation	+
H5	Cost efficiency mediates circularity → accounting performance	Indirect positive effect
H6	Reputation / lower transition risk mediates circularity → valuation	Indirect positive effect
H7	Firm size moderates circularity → performance	Conditional
H8	Measurement capability strengthens circularity → performance	+ interaction
H9	Enforcement / recovery infrastructure strengthens circularity → performance	+ interaction

Source: Authors' elaboration.

3. METHOD

This manuscript uses a structured evidence-synthesis design to assess the relationship between circular economy practices and firm financial outcomes, while specifying a replicable empirical strategy for a subsequent Southeast Asian FMCG panel study. The distinction between these two components is deliberate. The evidence synthesis interprets published empirical findings and official reports; the proposed panel design explains how company-level causal associations could be estimated with a newly assembled dataset. Since no harmonized firm-year file has been provided or analyzed for this manuscript, the article does not present fabricated descriptive statistics, regression estimates, p-values, or company rankings. The phrase "empirical evidence" in the title refers to the published empirical evidence synthesized here and to the

regional firm-level design proposed for direct testing. A journal submission that requires original panel estimates should add the dataset and results generated through the protocol below.

The evidence-synthesis component prioritizes peer-reviewed research published from 2021 onward, supplemented by authoritative reports from international organizations and reporting-standard bodies. The main selection criteria are relevance to circular economy practices at firm level; explicit discussion of financial, operational, market, or sustainability performance; methodological transparency; and applicability to manufacturing, consumer products, packaging, or supply-chain management. Studies focused solely on national macroeconomic circularity indicators are used only when they clarify the regional context. This is a structured narrative synthesis, not a claim to be a fully registered systematic review. It therefore does not report a PRISMA flow count or assert exhaustive coverage of every database.

3.1 Proposed population and sample

The target population for the proposed panel study comprises listed FMCG companies headquartered in or operating materially within Southeast Asia, including firms in food and beverages, household and personal care, packaged consumer goods, and related consumer-product manufacturing. The core sample should prioritize firms listed on exchanges in Indonesia, Malaysia, Singapore, Thailand, the Philippines, and Vietnam where consistent market and financial information is available. Companies with diversified operations can be included when FMCG activities are material and segment data allow reasonable classification. A company should not be excluded merely because it reports limited circularity information; doing so would create a sample selection problem in which only more transparent firms remain.

A practical study period would cover 2018–2025, subject to data availability and the timing of the latest audited statements. This window allows examination of pre-pandemic, pandemic, and post-pandemic years, while capturing the more recent expansion of sustainability reporting and packaging-related regulation. The researcher should build a company-year panel and record whether each observation is balanced or unbalanced. Delisted firms should be retained when historical data are available to reduce survivorship bias. Subsidiaries should not be counted separately when their financial statements are consolidated into a parent company, unless the analysis is explicitly conducted at subsidiary level and financial independence is established.

The sample selection process should be documented in a reproducible log: initial firms identified by sector and exchange classification; exclusions due to insufficient financial data; exclusions due to non-comparable business models; and final firm-year observations available for each model. Because the level of circularity disclosure may differ systematically by company size, ownership, and country, missing data should be analyzed rather than treated as random by default. Sensitivity analyses can compare a broad financial panel with the subset having sufficiently detailed environmental indicators. Differences between these samples should be reported transparently.

3.2 Data sources and collection protocol

Financial data should be collected from audited annual reports, exchange filings, and reputable financial databases where access is available. Market capitalization, shares outstanding, total assets, total liabilities, revenue, operating income, profit after tax, capital expenditure, cash flow, and leverage should be checked against audited disclosures for a subset of observations. Environmental data should be extracted from sustainability reports, integrated reports, environmental disclosures, and regulatory filings. Where available, waste generation, waste intensity, recycling or recovery rates, packaging tonnage, recycled content, reusable packaging, and environmental penalties should be recorded with their reporting boundaries and units.

The data dictionary should specify the source document, page number, reporting year, unit, conversion method, organizational boundary, and whether the value is directly reported or derived. For example, waste intensity might be measured as total waste generated divided by revenue or production volume; the denominator must be recorded because revenue-based intensity can change with prices even when physical waste does not. If a company reports only “percentage recyclable packaging,” that measure should not be treated as equivalent to the percentage actually collected and recycled. Similarly, an announced target should not be coded as an achieved outcome. The coding protocol should distinguish policy commitments, implementation activity, measured output, and independently verified performance.

Regulatory data should be collected from official legislation, government agency websites, enforcement notices, and international comparative databases. Researchers should code the date of adoption, effective date, scope, regulated products, producer responsibility requirements, reporting obligations, enforcement mechanism, and penalties where documented. A regulation index can measure the formal stringency of rules, while a separate enforcement index captures inspections, sanctions, or documented implementation. These constructs should not be collapsed without theoretical justification. If data on enforcement are incomplete, the limitation should be stated and alternative proxies tested.

3.3 Operationalization of variables

The dependent variables should cover both accounting performance and market valuation. Return on assets is calculated as net income divided by average total assets, where both beginning- and end-of-year values are available. Operating margin is operating income divided by revenue. Return on equity is net income divided by average shareholders' equity, but it should be interpreted cautiously where equity is negative or materially affected by leverage and buybacks. Tobin's Q can be approximated as market value of equity plus book value of liabilities divided by book value of assets, with the chosen formula applied consistently. Market-to-book ratio is a supplementary measure and should not be interpreted as a pure measure of environmental value because it is influenced by growth opportunities, accounting policy, and intangible assets.

Waste-management performance should be measured with several indicators rather than a single disclosure dummy. A preferred indicator is the change in waste intensity over time, with a negative change indicating improvement when the measure is defined as waste per unit of output or revenue. Complementary indicators include absolute waste generated, recovery or recycling rate, food or production loss where relevant, and the share of waste sent to landfill or incineration. Because the environmental meaning of recovery routes differs, the coding should retain disaggregated categories where possible. An index may be constructed only after standardizing components and testing whether the components reflect a coherent construct. Absolute and intensity measures should be analyzed separately to avoid rewarding firms whose sales growth masks rising total waste.

Green regulatory compliance can be operationalized through a transparent firm-year index covering (a) disclosed compliance with applicable environmental requirements, (b) reported violations or penalties, reverse-coded where appropriate, (c) certification or management systems, (d) completion of required environmental reporting, and (e) evidence of remediation after incidents. The index should not rely solely on the presence of a policy statement. A separate regulatory pressure variable can capture country-year differences in legal stringency and enforcement. Where a company has no reported violation, the value should be coded as "no violation disclosed" unless external sources confirm the absence of violations; non-disclosure should not automatically be interpreted as compliance.

Control variables should include firm size (log of total assets or revenue), leverage (total debt or liabilities relative to assets), sales growth, capital intensity, cash holdings, firm age, subsector, ownership concentration where available, and country-year effects. Inflation, exchange-rate exposure, and commodity-price shocks may be relevant in sensitivity tests because FMCG input costs can be affected by agricultural commodities, energy, and imported packaging materials. The model should also consider whether a firm is multinational or primarily domestic, since reporting systems, financing access, and supply-chain scale may differ. All monetary data should be converted consistently, but ratios should be calculated in the original reporting currency where conversion would not add analytical value.

Table 2. Variable definitions and proposed measures

Construct	Measure	Interpretation	Primary source
Accounting performance	ROA; operating margin; ROE	Profitability and operating returns	Audited annual reports
Market valuation	Tobin's Q; market-to-book	Investor valuation and growth expectations	Exchange filings / market data
Waste management	Waste intensity; absolute waste; recovery rate	Prevention, efficiency, and material recovery	Sustainability reports

Construct	Measure	Interpretation	Primary source
Green compliance	Compliance index; violations/penalties; remediation	Legal risk management and regulatory response	Company reports / regulators
Cost efficiency	COGS-to-sales; operating expense ratio; asset turnover	Cost and resource productivity channel	Financial statements
Environmental reputation	External ratings or disclosed controversies, if comparable	Credibility and stakeholder response	Independent databases / reports
Regulatory pressure	Country-year regulation and enforcement indicators	Institutional context	Official legislation / agencies
Controls	Size, leverage, growth, age, capital intensity	Firm-level confounders	Financial statements

Source: Authors' elaboration.

3.4 Econometric specification

The baseline model can be estimated using firm and year fixed effects. For accounting performance, the core specification is:

$$FP_{it} = \beta_0 + \beta_1 Waste_{i,t-1} + \beta_2 Compliance_{i,t-1} + \beta_3 Controls_{i,t-1} + \mu_i + \tau_t + \varepsilon_{it} \quad (1)$$

where FP is ROA or operating margin, Waste is waste-management performance, Compliance is the firm-level compliance index, μ_i captures time-invariant firm characteristics, and τ_t captures common year shocks. The one-period lag reduces simultaneity concerns and reflects the possibility that operational improvements affect financial results with a delay. Alternative specifications should use contemporaneous and two-year lagged variables as robustness checks. A parallel model can replace the accounting outcome with Tobin's Q or market-to-book ratio.

Firm fixed effects are appropriate when unobserved firm characteristics—such as management quality, brand positioning, and historical operating practices—are correlated with circular practices. Year effects absorb common shocks such as the pandemic, global commodity inflation, and broad market movements. Country-year controls can capture country-specific macroeconomic or regulatory changes, but care is needed where these absorb much of the variation in a country-level regulatory variable. Standard errors should be clustered at firm level; where the number of firms or countries is small, the inference strategy should be justified and small-cluster limitations acknowledged. Alternative estimators may be useful, but no estimator can correct poor measurement or unobserved time-varying confounding by itself.

To test mediation, the analysis should first estimate the association between circularity and the mediator, such as cost efficiency, and then estimate the outcome model with both circularity and the mediator included. Indirect effects can be assessed with bootstrap confidence intervals where the design supports this approach. Because accounting outcomes and mediators may be jointly determined, the results should be described as consistent with mediation rather than definitive causal mechanisms unless temporal ordering and identification assumptions are defensible. For moderation, interaction terms can be added between circularity and firm size, measurement capability, or regulatory context. Continuous variables should be centered where this aids interpretation, and marginal effects should be reported rather than interpreting the interaction coefficient in isolation.

Endogeneity is a central concern. Firms with strong financial performance may have greater capacity to invest in circular practices, creating reverse causality. Management quality can drive both environmental programs and profitability, while disclosure quality may be associated with firm visibility and investor attention. Lagged predictors, firm fixed effects, alternative measures, and placebo tests can reduce but not eliminate these concerns. If a credible regulatory change provides plausibly exogenous variation, a difference-in-differences design could compare firms more and less exposed to the policy before and after implementation. Such a design requires parallel pre-trends, no major concurrent shocks differentially affecting treatment and comparison groups, and careful treatment of staggered adoption. Instrumental-variable estimation should be used only where a defensible instrument and exclusion restriction exist; convenience instruments are not a solution to endogeneity.

3.5 Robustness, validity, and transparency

Robustness tests should replace ROA with operating margin and asset turnover, replace Tobin's Q with market-to-book, and estimate waste prevention separately from recovery. Researchers should test whether results are sensitive to the definition of waste intensity, the treatment of missing disclosures, the inclusion of firms with diversified operations, and the use of lagged explanatory variables. Outliers in financial ratios should be examined rather than automatically winsorized; any winsorization threshold should be pre-specified and reported. The study should also test whether the association differs by subsector, because beverage packaging, food waste, household chemicals, and personal-care packaging involve distinct material and regulatory conditions.

Construct validity requires special attention. Disclosure-based indices measure reported practices and reporting quality jointly. A company that publishes more data may appear more circular even if its physical performance is not superior. To address this, the study should separate outcome indicators from disclosure completeness and, where feasible, compare reported figures with assurance statements or external regulatory records. Inter-coder reliability should be assessed for qualitative coding, with a codebook, examples, and adjudication rules retained. If machine-assisted extraction is used, a human verification sample should be reported. Researchers should preserve an audit trail that links each coded value to a source and page number.

External validity is constrained by the availability of public data and by the composition of listed companies. Listed firms are often larger and more visible than privately held FMCG producers. Their reporting practices and financing access may not represent the full regional sector. The paper should therefore avoid generalizing findings to every FMCG firm in Southeast Asia. A future extension could combine the listed-company panel with a survey or case study of private suppliers, while keeping the different units of analysis analytically distinct. This design would help determine whether financial benefits are concentrated among large brand owners or also accrue to smaller firms participating in circular supply chains.

4. RESULTS

Because this manuscript does not contain a newly assembled firm-year dataset, this section reports an evidence-based synthesis of empirical findings and derives implications for the proposed Southeast Asian FMCG tests. It does not present original company-level regression results. This approach permits substantive analysis without creating unsupported numerical claims. The findings below should be read as patterns in the published evidence and as propositions to be tested directly in the regional panel, not as estimates from a sample of Southeast Asian firms.

Recent empirical research generally supports the proposition that circular economy practices can contribute to business performance, but the strength and pathway of the relationship are contingent. Yu et al. (2022) report that ecological design and investment recovery are associated with financial performance, with environmental and innovation performance acting as mediating mechanisms in a sample of Chinese manufacturers. Rodríguez-González et al. (2022) find that circular economy practices strengthen financial performance through sustainable supply-chain management in the automotive industry. These studies support the argument that circularity can create economic value when it is connected to operating and supply-chain capabilities rather than implemented as a stand-alone environmental initiative.

The evidence is not a license to assume that all circular practices generate the same return. Pan et al. (2024), using a meta-analytic structural equation modeling approach across 66 empirical studies and 13,643 manufacturing firms, examine how practices linked to eliminating waste and circulating products and materials relate to multiple performance outcomes. Their synthesis reinforces the importance of distinguishing practices and outcome categories. Evidence from adjacent sectors points in the same direction: Saiyed (2025) shows that recycled materials can lower lifecycle costs and emissions while strengthening environmental oversight, suggesting that circular inputs can carry both economic and sustainability benefits. Taken together, the evidence suggests that the expected average relationship is favorable, but an average effect can conceal economically meaningful heterogeneity.

For FMCG, this heterogeneity is likely to be pronounced. Waste prevention in a high-volume production line can create recurring savings through improved yield and lower material use. By contrast, launching a reusable packaging system may require new assets, reverse logistics, retailer coordination, and consumer adoption before savings emerge. A firm that shifts from virgin plastic to recycled content may experience higher input costs when recycled resin is scarce or inconsistent. The financial question should therefore be framed at two levels: whether circularity as a strategic portfolio is associated with improved performance, and which specific interventions create positive net present value under which operating conditions.

An important interpretive issue is the difference between environmental and financial performance. Improvements in one dimension may precede improvements in the other. An investment in collection infrastructure can improve recovery rates but raise operating expenses during rollout. A packaging redesign can reduce material use and shipping costs, but product damage may increase if the design is not sufficiently robust. Conversely, cost reduction may improve margins without a proportional improvement in circularity if the company merely transfers waste to another part of the value chain. Financial and environmental indicators should thus be examined jointly but not treated as interchangeable.

The strongest direct financial mechanism for waste management is the prevention of avoidable input loss. In production settings, material that is purchased but does not become saleable output represents a cost without corresponding revenue. Improvements in yield can lower material cost per unit, reduce waste treatment, and improve capacity utilization. These effects can be recorded through standard cost variances, scrap rates, spoilage rates, and yield measures. The financial return is more observable when firms maintain sufficiently granular operational data and when cost savings are not offset by higher quality-control or maintenance costs.

Mazzucchelli et al. (2022) distinguish waste treatment, reduction, and recycling, finding that the practices can affect financial performance through different routes, including brand reputation and direct cost effects. This distinction is especially useful for consumer products. Waste reduction may have a direct operational effect, while recycling and treatment can also influence external perceptions. Yet the effect of recycling on brand reputation depends on whether consumers and retailers can understand the claim and whether the reported recovery is credible. A company should not infer that a higher recycling percentage automatically produces a price premium or a higher valuation.

The main accounting risk is metric substitution. Firms may report a high recycling rate while generating more total waste as production expands. They may report a decline in waste sent to landfill while increasing incineration or exporting materials for processing. They may also report packaging that is “recyclable” based on technical design even where local collection systems are not capable of recovering it. A financially oriented study should therefore distinguish the physical quantity of waste generated, the intensity of waste relative to output, the share actually recovered, and the residual destination of materials. If the data permit, packaging placed on the market should be compared with post-consumer collection and recycling outcomes rather than relying only on design claims.

The evidence implies that H1 is plausible but conditional. Firms should be expected to benefit most where waste prevention reduces recurring expenditure, operational data identify root causes, and changes do not compromise safety or quality. The relationship may be weak or even negative during the initial implementation of new treatment or recovery systems. In a panel model, this suggests the importance of lagged measures, subsector controls, and separate tests for waste prevention and recovery. A single composite score may be useful for a summary model, but it should not be the only specification.

The financial logic of compliance is partly defensive. Compliance can prevent fines, legal costs, production delays, customer disqualification, and emergency redesign. The expected value of a compliance system therefore includes losses that do not occur, which are not always visible in accounting statements. This is particularly important for FMCG firms whose products move through multiple jurisdictions and retail channels. A regulatory failure involving packaging, hazardous substances, wastewater, or waste handling can affect a plant, a product line, or the reputation of an entire brand portfolio. Reliable compliance routines reduce the probability that environmental issues become costly operational events.

However, compliance should not be equated with a competitive advantage. When a requirement applies to all firms and is enforced consistently, compliance may be a cost of market access rather than a source of differentiation. Firms can still benefit by implementing requirements efficiently, anticipating future changes, and using compliance data to improve operations, but the market may not reward a company merely for meeting a minimum legal standard. The expected association between compliance and financial performance is therefore more likely to be positive where compliance reduces substantial downside risk or supports operational discipline, and weaker where the costs are high and the requirements provide little differentiation.

The regional setting complicates this relationship. A rule's formal existence does not establish uniform enforcement or equivalent waste-management capacity. Firms operating across Southeast Asia may face different reporting requirements and recovery infrastructure, and they may respond to regulation through a combination of substantive investment and symbolic disclosure. Researchers should separate regulatory stringency, implementation, enforcement, and firm-level compliance. This separation allows the model to test whether companies operating under stronger institutions experience a different financial return from circular investments, while avoiding the assumption that a country with more formal rules necessarily has better environmental outcomes.

The implications for H2 are consequently nuanced. Stronger compliance is expected to be associated with better accounting performance over a suitable horizon, particularly through lower risk and improved process discipline. Yet the short-run association can be negative when compliance requires capital expenditure, supplier substitution, or system upgrades. The empirical model should examine both contemporaneous and lagged relationships and test whether the association differs between firms with high and low exposure to packaging regulation. Penalty data, when available, should be analyzed as a separate risk outcome rather than folded into a generic sustainability score.

Market valuation is shaped by expectations rather than only by realized accounting returns. A credible circular strategy can signal that management is preparing for regulatory change, protecting material access, and investing in products and processes that may remain viable as environmental expectations evolve. This may lower investors' estimates of future downside risk. A market response is more likely when investors can connect reported circularity to financially material exposure, such as packaging obligations, resource-price volatility, or customer requirements. General sustainability claims are less informative when they are not tied to measurable operating indicators and financial implications.

The systematic review by Kanzari et al. (2022) emphasizes the need to improve the financial evaluation of circular business models across transition phases. Their analysis is relevant to market valuation because it highlights the difference between prospective assessments made before investment and retrospective evaluation after implementation. Investors may need to judge a firm before the benefits are fully realized, but they will also seek evidence that projects are progressing toward the expected returns. This creates a premium on transparent capital-allocation logic: what is being invested, which costs are expected to fall, when benefits should emerge, and what indicators will be used to evaluate success.

For FMCG companies, brand and retailer relationships may create additional valuation channels. A firm with credible waste and packaging performance may be better positioned to preserve access to major retailers or protect consumer trust. However, those advantages should not be assumed to be uniform. Product category, market share, price positioning, consumer awareness, and the availability of substitutes can determine whether environmental differentiation affects sales. A firm can also face a credibility penalty if it publicizes circular ambitions while absolute packaging use continues to increase. Thus, H3 and H4 should be tested using market-based measures while controlling for size, growth, leverage, and sector-specific valuation differences.

The measurement problem remains substantial. Tobin's Q and market-to-book ratios are influenced by intangible assets, growth expectations, accounting rules, and capital structure. Environmental information may be incorporated into prices through broad risk assessments rather than through an identifiable "circularity premium." An association between circular performance and valuation does not by itself establish that investors explicitly reward circularity. Researchers should therefore avoid interpreting the

coefficient as a direct measure of investor preference unless the design includes an event study, analyst forecast analysis, or another approach that identifies a market response to new information.

A key contribution of an accounting-oriented approach is to trace circular practices through financial statements. Waste prevention may reduce raw-material consumption and manufacturing overhead. If the cost savings are not offset by implementation expenses, gross margin may improve. Improvements in yield and throughput may increase revenue generated from a given asset base, improving asset turnover. Better recovery systems may generate secondary-material revenue or reduce disposal costs, although revenue from recovered material may be immaterial relative to total sales. Compliance systems can reduce provisions, penalties, and disruption costs, but the avoidance of a hypothetical fine will not appear as a conventional gain in the income statement.

Capital investment creates a different pattern. Reusable packaging, sorting equipment, water-treatment systems, traceability technology, and redesign may require initial cash outflows. The investment can increase assets and depreciation before the operating benefits materialize. As a result, ROA may decline temporarily even if the project has a positive net present value. Cash-flow analysis and project-level capital budgeting are therefore essential complements to annual accounting ratios. Management should evaluate the investment using discounted cash flow, sensitivity analysis, scenario planning, and payback measures, while recognizing that conventional financial models may understate avoided regulatory risk or resilience benefits when these are difficult to quantify.

Working capital may also change. Reusable systems can require deposits, returnable inventory, cleaning capacity, and additional handling. Recycled materials may involve longer lead times or minimum purchase quantities, increasing inventory requirements. Conversely, improved resource planning and better production yields may reduce obsolete stock and write-offs. These effects can offset or amplify profitability changes. A firm-level study that focuses only on ROA may miss working-capital pressures; including cash conversion cycle, inventory turnover, and operating cash flow can provide a more complete picture where data are comparable.

Accounting classification and comparability are practical concerns. Environmental expenditure may be embedded in capital expenditure, operating expense, research and development, logistics, or general overhead. Companies rarely report all circularity-related costs as a separate line item. The proposed panel can estimate associations between disclosed circular practices and aggregate performance, but it cannot claim to isolate the exact accounting return of each intervention unless project-level cost data are available. A complementary management-accounting case study could trace cost pools, activity-based costing, material-flow cost accounting, and investment appraisal at facility or product level. Such evidence would help explain why similar circularity scores may be associated with different firm outcomes.

The transition to circularity may follow a J-shaped financial pattern. During early implementation, firms incur costs for redesign, supplier qualification, data systems, training, and infrastructure. As the initiative matures, learning, scale, and process standardization may reduce unit costs. Eventually, marginal savings may decline as the easiest waste-reduction opportunities are exhausted. A linear model can estimate an average association but may fail to capture this sequence. Researchers should consider squared terms, adoption-stage indicators, or event-time specifications where the number of observations permits. These approaches should be theoretically motivated and not selected merely because they produce statistically significant coefficients.

Timing can differ by practice. Material efficiency improvements may influence margins within a production cycle, whereas reusable packaging systems may require multiple rounds of consumer adoption and reverse logistics development. Regulatory compliance investments can produce immediate expense and delayed risk reduction. Market valuation may respond rapidly to new information, while accounting ratios change only after the operating model is implemented. The empirical design should therefore avoid assuming that all circular practices have a common lag. Distributed-lag models or separate tests for one- and two-year lags can help reveal whether the effects unfold over time.

A nonlinear view also improves managerial interpretation. A weak contemporaneous association does not necessarily imply that a circular initiative is uneconomic; it may indicate that the firm is still in the

investment phase. Equally, a positive short-run result may reflect one-off savings rather than a durable capability. Managers should distinguish recurring benefits from temporary effects, and researchers should test whether performance gains persist. The appropriate horizon depends on the technology, product category, regulatory environment, and expected life of the investment.

FMCG is not a homogeneous industry. Food and beverage producers may prioritize food loss, water, agricultural residues, and packaging. Household and personal-care companies may face different material combinations, chemical requirements, and refill opportunities. Producers of packaged staples may compete primarily on price and distribution, while premium brands may have more room to differentiate through packaging and product stewardship. These differences affect both the cost of circular interventions and the likelihood that consumers or retailers reward them. A pooled sector estimate should therefore be supplemented with subsector interactions or stratified analyses, provided sample sizes are adequate.

Country heterogeneity matters for similar reasons. Collection infrastructure, recycling markets, enforcement, logistics, energy costs, and consumer practices influence the feasibility of circular models. A company may be able to source high-quality recycled material in one market but face inconsistent supply in another. Regional manufacturers may also choose different packaging specifications to comply with local requirements, creating scale economies or fragmentation costs. Firm and year fixed effects can address some unobserved heterogeneity, but they do not replace explicit measurement of regulatory context and infrastructure. Researchers should resist the temptation to treat national development indicators as complete proxies for institutional quality.

Multinational firms create a further measurement challenge. Consolidated reports may combine operations across countries, while circularity data may cover only selected markets or facilities. Financial outcomes may be consolidated at the parent level, making it difficult to match a country-level regulatory variable to the firm's actual exposure. The coding protocol should document reporting boundaries and, where feasible, calculate exposure-weighted regulatory measures based on revenue, production, or assets in each market. If such data are unavailable, the limitation should be acknowledged and conclusions restricted to the level that the data support.

A company's disclosure can be an imperfect proxy for its environmental performance. Firms with more resources may publish detailed reports, use external assurance, and adopt standardized metrics. Their higher disclosure score may reflect reporting capacity as much as actual circularity. Companies with poor environmental outcomes may also disclose selectively, emphasizing relative improvements or future targets while omitting absolute quantities. This creates a risk that a disclosure-based circularity index is positively correlated with firm size and investor visibility, even if the physical outcome is not superior.

A robust empirical study should distinguish at least three layers: policy and commitment, implementation and investment, and measured outcome. For example, a packaging target belongs in the commitment layer; installation of new sorting equipment belongs in the implementation layer; and a verified reduction in absolute waste belongs in the outcome layer. External assurance can increase confidence in the data but does not by itself establish that the underlying performance is sufficient. Researchers should record whether metrics are assured, which facilities are covered, whether data are restated, and whether reported values are absolute or intensity-based.

Greenwashing risk has financial implications. If stakeholders later discover that claims were exaggerated or boundaries were misleading, the firm may face reputational damage, regulatory scrutiny, or litigation. The short-run market response to a sustainability announcement may therefore be reversed when evidence fails to support the claim. This possibility strengthens the case for longitudinal measures and external controversy data, while also cautioning against assuming that all disclosure is beneficial. The most decision-useful reporting links environmental metrics to capital allocation, operating costs, risk exposure, and progress against time-bound targets.

The evidence synthesized in this article is broadly consistent with H1 and **H3:** waste-management performance can improve financial outcomes through material efficiency, reduced disposal costs, operational reliability, and reputation. However, the association should be expected to vary by practice, reporting boundary, and implementation stage. Waste prevention is likely to provide the clearest direct cost pathway,

while recycling and recovery may have more context-dependent benefits. For market valuation, credibility and expected persistence are likely to matter as much as the headline recovery rate.

The evidence is also consistent with H2 and H4 in the sense that compliance can reduce expected downside risk and signal preparedness for regulatory change. Yet the financial relationship is likely to be more time-dependent than a simple positive coefficient implies. Compliance expenditure may depress margins in the short run, and minimum compliance may not differentiate firms once a rule is universally enforced. The proposed model should therefore test lags, exposure differences, and the distinction between regulatory stringency and firm-level compliance.

H5 and H6 reflect plausible mechanisms rather than conclusively established causal pathways for Southeast Asian FMCG companies. Cost efficiency is a measurable mediator if financial statements and operational data are sufficiently granular. Reputation and perceived risk are harder to observe, and their measurement must avoid circular reasoning—for example, using market valuation itself as both a mediator and outcome. External brand metrics, controversy indicators, analyst forecasts, or event-based market responses may strengthen the design. If these measures are unavailable, the study should present mediation claims as exploratory and focus on the direct association.

H7–H9 emphasize boundary conditions. Firm size may support scale economies but also bring organizational complexity. Digital measurement can improve data quality and process control, but only if systems are integrated into managerial routines. Regulatory enforcement and recovery infrastructure may strengthen the payoff to circular practices by improving incentives and the feasibility of material recovery. These conditions should be tested with parsimonious interaction models and interpreted through marginal effects. The central result of the evidence synthesis is therefore not that circularity always increases profit, but that financial value is most plausible when environmental action is operationally effective, credibly measured, and aligned with the institutional and commercial setting.

5. DISCUSSION

5.1 Theoretical implications

The synthesis advances the NRBV by treating circular economy practices as a portfolio of capabilities with different cost structures and financial pathways. The distinction between waste prevention, recovery, and compliance helps explain why studies may produce mixed results when they aggregate diverse practices. The relevant strategic resource is not the circular initiative in isolation, but the capability to redesign processes, coordinate suppliers, measure material flows, and capture the resulting operational gains. This interpretation aligns with recent empirical work that links circular practices to performance through environmental improvement, innovation, and supply-chain management (Yu et al., 2022; Rodríguez-González et al., 2022; Pan et al., 2024).

The article also connects institutional theory with firm-level accounting. Regulation shapes the economic consequences of circularity, but the institutional environment should be decomposed into formal rules, enforcement, and enabling infrastructure. This distinction is important for Southeast Asia because a firm's exposure to regulation does not necessarily predict the availability of collection and recycling services. Regulatory pressure can increase the expected cost of inaction, while infrastructure determines whether a proposed circular solution is technically and commercially feasible. A firm may comply with formal requirements yet struggle to create a closed-loop material system if downstream recovery markets remain weak.

Signaling theory provides a further contribution by emphasizing the quality of environmental information. Investors are more likely to respond to circularity when reported metrics provide credible information about future cash flows and risks. The signal is strongest when a company demonstrates a sustained decline in waste intensity, provides absolute quantities, explains capital allocation, and discloses the limits of its recovery systems. This approach shifts attention from the volume of sustainability disclosure to its decision-usefulness. It also explains why disclosure quality should be modeled separately from physical circular performance.

5.2 Implications for management accounting and capital allocation

Managers should evaluate circular initiatives using project-level economics rather than relying solely on high-level ESG scores. A capital proposal should identify the baseline material flow, expected reduction in waste, required investment, operating and maintenance costs, expected savings, potential revenue from recovered materials, and risks associated with quality or supply. It should also state the time horizon over which benefits are expected and identify the operational owner responsible for realizing them. Where benefits include avoided penalties or reduced disruption, the business case should disclose the assumptions used to estimate those avoided costs rather than presenting them as certain savings.

Material-flow cost accounting can help connect physical losses to monetary consequences. By tracing material inputs, outputs, and losses across production stages, managers can identify costs that conventional accounting systems may bury in overhead. Activity-based costing can be useful when circular initiatives alter logistics, cleaning, collection, or quality-control activities. Standard costing and variance analysis can track changes in yield, scrap, and packaging usage over time. These tools do not replace financial statements; they provide the operational detail needed to interpret whether a circular investment is producing the expected economics.

Capital budgeting should incorporate more than a single payback period. A project can have a long payback but reduce exposure to a foreseeable regulatory requirement or preserve access to a major retailer. Conversely, a project can show attractive environmental metrics but fail financially if consumer adoption is low or logistics costs are underestimated. Scenario analysis should test changes in recycled-material prices, collection rates, return rates, energy costs, and regulatory timing. Sensitivity analysis should identify the break-even conditions under which a project remains economically viable. The resulting analysis can support staged investment, pilot programs, and decision gates before full rollout.

Management should also avoid optimizing one metric at the expense of the system. Lightweighting that increases product damage may raise food waste or returns. Reusable packaging may reduce single-use material but increase water, energy, and transport requirements. Recycling may be appropriate for some material streams but less effective than prevention for others. The financial and environmental evaluation should therefore use a life-cycle perspective where material trade-offs are significant. In practice, the firm can begin with operationally measurable improvements while commissioning a more comprehensive life-cycle assessment for major packaging redesigns.

5.3 Implications for financial reporting and investor communication

Financial reporting should make circularity legible to capital providers without overstating precision. Companies should disclose the most financially material waste and packaging indicators, explain changes in measurement boundaries, and distinguish targets from achieved results. Where circular investment is material, management should describe the expected operating mechanism and the time horizon for benefits. This does not mean every sustainability report should assign a monetary value to each environmental outcome; it means that environmental indicators should be connected to financial risk, cost structure, capital allocation, and strategic resilience where those connections are supportable.

Investors and analysts should avoid interpreting a single circularity score as a sufficient indicator of performance. They should ask whether absolute waste is falling, whether intensity improvements persist, whether recovery claims are based on actual collection, and whether the firm has exposure to regulatory changes in its principal markets. They should also consider whether circular investments are funded through sustainable cash generation or require substantial additional leverage. A credible strategy may create long-term value while depressing short-run returns, but management should explain this trade-off and provide milestones against which progress can be evaluated.

Reporting standards can improve comparability, but standardization alone does not solve every problem. Companies may have different product portfolios, waste streams, and regulatory exposures. A useful disclosure framework combines consistent core metrics with explanations of business-specific materiality. External assurance can improve confidence in selected data, particularly when metrics are used to support investor-facing claims. Nonetheless, assurance should not be treated as a substitute for transparent boundaries, sound internal controls, and evidence that operational outcomes are improving.

5.4 Implications for regulators and regional cooperation

Regulators can improve the investment environment by providing clear implementation schedules, consistent definitions, credible enforcement, and practical guidance for reporting. Predictability allows firms to plan packaging redesign and recovery investments over several years rather than reacting to abrupt changes. Producer responsibility schemes should be designed with attention to actual collection and recycling capacity, not merely the formal assignment of financial responsibility. Where smaller suppliers face barriers to compliance, technical assistance and shared infrastructure may reduce the risk that regulation produces disproportionate costs without meaningful environmental gains.

Regional cooperation can also help reduce fragmentation. FMCG supply chains frequently cross borders, while packaging specifications and waste rules may differ by market. More consistent definitions of recyclable packaging, recycled content, recovery, and reporting boundaries could reduce compliance costs and improve data comparability. Cooperation among firms, retailers, recyclers, and public agencies may support stable demand for recovered materials and improve the economics of collection systems. These measures should be evaluated not only by the number of policies adopted but by actual material recovery, waste prevention, and financial feasibility.

Policy design should recognize that formal compliance and circular outcomes are related but distinct. A firm may meet a reporting obligation without materially reducing waste, while a firm may implement efficient waste prevention before regulation explicitly requires it. Regulatory evaluation should therefore track both process indicators—such as compliance submissions and inspections—and outcome indicators such as waste generation, collection, and recovery. This distinction helps avoid incentives that reward reporting activity without changing material flows.

5.5 Limitations and research agenda

The main limitation of this manuscript is the uneven availability and comparability of circularity data. Sustainability reports differ in coverage, definitions, assurance, and reporting boundaries. Some firms disclose absolute waste quantities, while others report only selected rates or targets. The most transparent companies may be systematically larger or more profitable, which can create selection bias. Future studies should document missingness, compare firms with and without detailed disclosure, and consider methods for selection sensitivity where appropriate. The data should also distinguish a true zero from non-disclosure. A third limitation is that firm-level financial ratios may not capture the full value of circular practices. Environmental risk reduction, stakeholder trust, and supply-chain resilience can be economically important but difficult to monetize. Conversely, positive accounting performance may reflect unrelated factors such as pricing power, acquisitions, or commodity cycles. Future work should triangulate financial statements with operational measures, project-level cost data, and qualitative evidence from managers. A mixed-method design can explain why an intervention succeeds in one setting and fails in another without treating all firms as comparable observations.

Further research should examine regulatory changes using quasi-experimental designs where credible comparison groups exist. Event studies could investigate market responses to verified circularity announcements, regulatory penalties, or new packaging requirements. Longitudinal studies could test whether initial cost burdens are followed by operating gains. Product-level analyses could compare reusable, refill, recycled-content, and lightweight packaging under different consumer and infrastructure conditions. Research should also examine private and small firms, which may face greater financing constraints and less reporting capacity than listed companies.

6. CONCLUSION

This article examines how circular economy practices may affect financial performance and market valuation among FMCG companies in Southeast Asia, with particular attention to waste management and green regulatory compliance. The central conclusion is that circularity can create financial value, but its effects depend on the specific practice, implementation horizon, measurement quality, and institutional context. Waste prevention offers a relatively direct pathway through lower material use, better yields, and reduced disposal costs. Recycling and recovery can add value through material recovery and reputation, but their

economics depend on collection infrastructure, material quality, and actual end markets. Green regulatory compliance can reduce expected penalties and transition risk, although its short-run costs may precede financial benefits.

The analysis also shows why accounting and market outcomes should be examined separately. Operating margins and asset returns reflect realized financial performance, while market valuation captures expectations about future cash flows and risk. Circular investment may initially reduce accounting returns while supporting longer-term resilience, and investors may not reward sustainability claims that lack credible evidence. The most informative analysis therefore combines financial ratios, market-based indicators, operational waste metrics, and regulatory information. It also separates policy commitments from implementation and verified outcomes.

For managers, the practical implication is to connect circular initiatives to explicit cost drivers, capital-budgeting assumptions, operational responsibilities, and measurable milestones. For accountants, the priority is to improve the traceability of material losses and the comparability of circularity-related expenditure and outcomes. For investors, the key is to evaluate the credibility and financial materiality of environmental information rather than rely on headline claims. For regulators, predictable rules and investment in recovery infrastructure can improve both compliance and the feasibility of circular business models. The article's proposed panel-data design offers a path to testing these relationships systematically across Southeast Asian FMCG companies. Firm and year fixed effects, lagged explanatory variables, transparent variable definitions, and robustness checks can improve inference, while quasi-experimental designs may be appropriate where regulatory changes provide credible variation.

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REFERENCES

Antonioli, D., Ghisetti, C., Mancinelli, S., & Mazzanti, M. (2022). Sustainable production: The economic returns of circular economy practices. Business Strategy and the Environment, 31(5), 2603–2617. https://doi.org/10.1002/bse.3046

ASEAN Secretariat. (2021). ASEAN Framework of Circular Economy for the ASEAN Economic Community. https://asean.org/

ASEAN. (2021). ASEAN State of Climate Change Report. Association of Southeast Asian Nations. https://asean.org/book/asean-state-of-climate-change-report/

Asian Development Bank. (2022). Asian Development Outlook 2022: Mobilizing Taxes for Development. https://www.adb.org/publications/asian-development-outlook-2022

Asian Development Bank. (2023). Asian Development Outlook 2023: Highlights of the Asia and Pacific Economic Outlook. https://www.adb.org/publications/asian-development-outlook-april-2023

Ellen MacArthur Foundation. (2021). The Global Commitment 2021 progress report. https://www.ellenmacarthurfoundation.org/global-commitment

Ellen MacArthur Foundation. (2021). Universal Circular Economy Policy Goals: Enabling the Transition to Scale. https://www.ellenmacarthurfoundation.org/

Ellen MacArthur Foundation. (2022). The Global Commitment 2022 progress report. https://www.ellenmacarthurfoundation.org/global-commitment

Ellen MacArthur Foundation. (2023). The Global Commitment 2023 progress report. https://www.ellenmacarthurfoundation.org/global-commitment

European Commission. (2021). Guidance on the implementation of the EU waste framework and circular economy policies. https://environment.ec.europa.eu/topics/waste-and-recycling_en

European Commission. (2022). EU Strategy for Sustainable and Circular Textiles. https://environment.ec.europa.eu/strategy/textiles-strategy_en

European Environment Agency. (2022). Circular economy and the bioeconomy: Partners in sustainability. https://www.eea.europa.eu/

Global Reporting Initiative. (2021). GRI 301: Materials 2016 (standard page and updates). https://www.globalreporting.org/standards/

Global Reporting Initiative. (2021). GRI 306: Waste 2020. https://www.globalreporting.org/standards/standards-development/topic-standard-for-waste/

Global Reporting Initiative. (2021). GRI 308: Supplier Environmental Assessment 2016 (standard page and updates). https://www.globalreporting.org/standards/

Gonçalves, B. S. M., de Carvalho, F. L., & Fiorini, P. de C. (2022). Circular economy and financial aspects: A systematic review of the literature. Sustainability, 14(5), 3023. https://doi.org/10.3390/su14053023

IFRS Foundation. (2023). IFRS S1 General Requirements for Disclosure of Sustainability-related Financial Information. https://www.ifrs.org/issued-standards/ifrs-sustainability-standards-navigator/ifrs-s1-general-requirements/

IFRS Foundation. (2023). IFRS S2 Climate-related Disclosures. https://www.ifrs.org/issued-standards/ifrs-sustainability-standards-navigator/ifrs-s2-climate-related-disclosures/

International Energy Agency. (2023). Material Efficiency in Clean Energy Transitions. https://www.iea.org/

International Finance Corporation. (2022). Sustainability and ESG Trends in Emerging Markets. https://www.ifc.org/

International Organization for Standardization. (2021). ISO 14001 Environmental management systems—Requirements with guidance for use. https://www.iso.org/standard/60857.html

International Organization for Standardization. (2021). ISO 14040 Environmental management—Life cycle assessment—Principles and framework. https://www.iso.org/standard/37456.html

Kanzari, A., Rasmussen, J., Nehler, H., & Ingelsson, F. (2022). How financial performance is addressed in light of the transition to circular business models: A systematic literature review. Journal of Cleaner Production, 376, 134134. https://doi.org/10.1016/j.jclepro.2022.134134

Magnano, D. G., Grimstad, S. M. F., Glavee-Geo, R., & Anwar, F. (2024). Disentangling circular economy practices and firm's sustainability performance: A systematic literature review of past achievements and future promises. Journal of Environmental Management, 353, 120138. https://doi.org/10.1016/j.jenvman.2024.120138

Mazzucchelli, A., Chierici, R., Di Gregorio, A., & Bissola, R. (2022). Do circular economy practices affect corporate performance? Evidence from Italian large-sized manufacturing firms. Corporate Social Responsibility and Environmental Management. https://doi.org/10.1002/csr.2298

Mustofa, I., Rahmanda, Y., & Ramadhan, R. A. (2026). Green accounting disclosure and investor valuation: The moderating role of corporate governance in publicly listed coal sectors. Advanced Business Journal, 2(3), [pages]. [DOI]

Nosková, M., Taušl Procházková, P., & Zemanová, V. (2024). The relationship between the circular economy and business performance: A systematic literature review. Journal of Business Economics and Management, 25(3), 474–493. https://doi.org/10.3846/jbem.2024.21413

OECD. (2021). Extended Producer Responsibility: Updated Guidance for Efficient Waste Management. https://doi.org/10.1787/9789264256385-en

OECD. (2021). Policies to Reduce Microplastics Pollution in Water: Focus on Textiles and Tyres. https://doi.org/10.1787/7ec7e5ef-en

OECD. (2022). Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options. OECD Publishing. https://doi.org/10.1787/de747aef-en

OECD. (2022). Global Plastics Outlook: Policy Scenarios to 2060. OECD Publishing. https://doi.org/10.1787/aa1edf33-en

OECD. (2023). Towards Eliminating Plastic Pollution by 2040: A Policy Scenario Analysis. https://www.oecd.org/environment/plastics/

Pan, X., Wong, C. W. Y., Wong, C. Y., Boon-itt, S., & Li, C. (2024). The influences of circular economy practices on manufacturing firm's performance: A meta-analytic structural equation modeling study. International Journal of Production Economics. https://doi.org/10.1016/j.ijpe.2024.109267

Phattanaviroj, T., & Pattaradej, R. (2025). Green supply chain management and its impact on firm competitiveness in emerging markets. Advanced Business Journal, 1(1), 1–10. https://advancedbusinessjournal.com/index.php/abj/article/view/1

Quaser, N. (2026). Driving market confidence: The role of ESG reporting in green finance transparency. Advanced Business Journal, 2(1), 33–44. https://doi.org/10.65875/4cr05625

Rodríguez-González, R. M., Maldonado-Guzmán, G., Madrid-Guijarro, A., & Garza-Reyes, J. A. (2022). Does circular economy affect financial performance? The mediating role of sustainable supply chain management in the automotive industry. Journal of Cleaner Production, 379, 134670. https://doi.org/10.1016/j.jclepro.2022.134670

Saiyed, S. (2025). Circular economy in civil engineering: The role of recycled construction materials in economic and sustainability performance. Advanced Business Journal, 1(2), 41–48. https://advancedbusinessjournal.com/index.php/abj/article/view/10

Triguero, A., Moreno-Mondéjar, L., & Davia, M. A. (2023). Circular economy and firm performance: The influence of product life cycle analysis, upcycling, and redesign. Sustainable Development. https://doi.org/10.1002/sd.2509

UNCTAD. (2023). Trade and Environment Review 2023: Building a Sustainable and Resilient Ocean Economy Beyond 2030. https://unctad.org/publication/trade-and-environment-review-2023

UNEP. (2021). Food Waste Index Report 2021. https://www.unep.org/resources/report/unep-food-waste-index-report-2021

UNEP. (2021). From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution. https://www.unep.org/resources/pollution-solution-global-assessment-marine-litter-and-plastic-pollution

UNEP. (2022). Sustainable Consumption and Production: A Handbook for Policymakers. https://www.unep.org/

UNEP. (2023). Turning off the Tap: How the World Can End Plastic Pollution and Create a Circular Economy. https://www.unep.org/resources/turning-off-tap-end-plastic-pollution-create-circular-economy

UNEP. (2024). Global Waste Management Outlook 2024: Beyond an Age of Waste—Turning Rubbish into a Resource. https://www.unep.org/resources/global-waste-management-outlook-2024

United Nations Environment Programme Finance Initiative. (2021). Financing Circularity: Demystifying Finance for Circular Economies. https://www.unepfi.org/

United Nations. (2023). The Sustainable Development Goals Report 2023. https://unstats.un.org/sdgs/report/2023/

World Bank. (2021). Market Study for Thailand: Plastics Circularity Opportunities and Barriers. https://openknowledge.worldbank.org/

World Bank. (2022). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 (updated resource page). https://datatopics.worldbank.org/what-a-waste/

World Bank. (2023). Plastic Waste Discharges from Rivers and Coastlines in Indonesia. https://www.worldbank.org/en/country/indonesia

World Bank. (2024). Plastic Pollution and Circular Economy: Regional Knowledge and Country Resources. https://www.worldbank.org/en/topic/urbandevelopment

World Economic Forum. (2021). The Future of Nature and Business: New Nature Economy Report II. https://www.weforum.org/reports/new-nature-economy-report-ii-the-future-of-nature-and-business/

Yu, Y., Xu, J., Zhang, J. Z., Wu, Y., & Liao, Z. (2022). Do circular economy practices matter for financial growth? An empirical study in China. Journal of Cleaner Production, 370, 133255. https://doi.org/10.1016/j.jclepro.2022.133255