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Article

## A Strategy-Oriented Study on the Mechanism by Which Corporate Social Responsibility Influences Sustainable Performance from a Supply Chain Collaboration Perspective

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**Abstract:** In a highly interconnected and increasingly regulated environment, corporate social responsibility (CSR) is evolving from a compliance burden into a strategic lever for supply chain collaboration and sustainable performance. This study develops a strategy-oriented mechanism linking CSR intensity, collaborative capability, and sustainable performance, and examines how this mechanism operates in complex supply networks. We conceptualize collaborative capability through information sharing, joint decision-making, and coordinated resource allocation, and identify data governance, process intelligence, organizational coordination, and ecosystem openness as key amplifiers of this capability. Security and compliance are treated as gating conditions that shape the effectiveness and scalability of CSR initiatives. The paper explains how CSR practices enhance environmental, social, and governance outcomes, while simultaneously improving operational resilience through information symmetry, risk sharing, and co-innovation among supply chain partners. Building on this framework, we propose phased investment paths, portfolio-based governance of CSR projects, and platform-oriented scaling strategies that align CSR with core business objectives. The study further offers context-specific managerial guidance for firms operating under varying regulatory pressures, digital maturity levels, and ecosystem structures. Overall, the findings clarify the strategic role of CSR in strengthening collaborative advantage and provide a structured basis for designing, evaluating, and continuously improving CSR-driven supply chain strategies.

**Keywords:** corporate social responsibility; supply chain; sustainable performance; governance; collaboration; risk management

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### 1. Introduction

#### 1.1. Research Background and Significance

Digitalization and intelligence are transforming enterprises from being resource-driven to operating based on data and algorithms. In multi-geography and multi-tier supply chains, corporate social responsibility (CSR) externalities propagate swiftly across interconnected nodes, influencing factors such as cost, delivery timelines, regulatory compliance, and brand trust. These responsibility outcomes, in turn, impact governance and capital allocation through mechanisms like financing costs, credit ratings, and environmental, social, and governance (ESG) assessments. The increasing stringency of policies related to data security, privacy, and environmental standards is altering the pace of transformation and the marginal returns on investments. This necessitates significant investments in IT/OT convergence, process redesign, and talent development through cross-functional collaboration. Consequently, there is a pressing need for a transparent,

comparable, and traceable evaluation system that can convert contract and report text, as well as operational and risk data, into actionable indicators [1]. Such a system would empower managers and investors with strategic tools and facilitate governance tailored to specific industries and firm sizes [2, 3].

### *1.2. Research Status at Home and Abroad*

Existing research can be broadly categorized into two primary perspectives: the capability-performance pathway and the governance-organization lens. The capability-performance pathway highlights that investments in IT infrastructure, improvements in data quality, and process reengineering are closely linked to enhanced operational outcomes, such as increased efficiency, improved accuracy, and heightened responsiveness. On the other hand, the governance-organization lens underscores the importance of factors such as top management support, cross-functional collaboration, and structured change management in determining the success of implementation and scalability. International studies often emphasize the role of data assets as inventory-like resources, the complementarities of platforms, and the impact of logistical frictions as critical factors influencing adoption and performance outcomes. These studies frequently utilize event-based methodologies, such as analyzing policy shocks or technology rollouts, to assess differences in resilience and adaptability. In contrast, domestic research tends to focus more on the regulatory environment, coordination across industry chains, and mechanisms for supplier governance. Methodologically, advancements in text mining have transitioned from basic bag-of-words approaches to leveraging large language models for cross-genre information extraction, significantly enhancing recall and consistency across diverse sources such as annual reports, CSR disclosures, contracts, and audit documents. These advancements also enable tagging of uncertainties and linking evidence to outputs. However, significant challenges remain, including imperfect semantic alignment across sources, inconsistent indicator definitions across industries and firm sizes, and a lack of robust mappings from textual indicators to causal performance outcomes. There is a pressing need for a unified and standardized framework that integrates CSR measurement with supply chain collaboration capabilities, risk management, and time-sensitive decision-making, while ensuring external validity and auditability.

### *1.3. Theoretical Foundations and Technical Approach: Concepts and Methods*

#### *1.3.1. Conceptual Framework and Research Propositions*

A model has been developed with corporate social responsibility (CSR) intensity as the input, collaborative capability as the mediator, and sustainable performance as the output. Environmental, social, and governance practices are linked to outcomes such as environmental performance, social performance, operational resilience, and financial results. These connections are facilitated through mechanisms like shared data and standards, joint planning and forecasting, collaborative replenishment and production, joint risk management and emergency response, and co-innovation with ecosystem partners. Mechanistically, the information-symmetry pathway reduces adverse selection and coordination costs by enhancing carbon accounting, labor compliance, and traceability transparency. The risk-sharing pathway mitigates the tail risk of disruptions through the implementation of responsibility clauses, joint insurance arrangements, and coordinated drills. Meanwhile, the co-innovation pathway accelerates the diffusion of innovations and improves unit productivity by leveraging green materials and circular models. Security and compliance act as critical thresholds for scaling up, while factors such as data governance, process intelligence, organizational coordination, and ecosystem openness amplify the efficiency of converting CSR efforts into performance outcomes. This framework generates testable propositions regarding mediation effects, threshold impacts under conditions of high regulation or complexity, and the potential for enhanced innovation gains in more open ecosystems.

### 1.3.2. Methods and Data

A mixed-method approach has been adopted, integrating large language model (LLM)-driven text intelligence with operational data to enable scalable and auditable measurement processes. A comprehensive multi-source corpus and enterprise data lake have been constructed, incorporating data from annual and sustainability reports, supplier manuals, contracts, audits, procurement and logistics events, quality inspections, and IoT telemetry. Document metadata has been standardized using firm, supplier tier, product, and region keys to ensure consistency. A unified prompt schema has been employed to extract corporate social responsibility (CSR) commitments, clause strength, evidence snippets, uncertainty tags, and sentiment. These elements are aligned with domain ontologies and master data domains to maintain consistent labeling across time periods and entities. Quality control measures, including synonym and hypernym merging and contradiction checks, have been applied to generate CSR and collaborative capability scores with confidence intervals [4, 5]. Bayesian shrinkage and cross-validation techniques have been utilized to calibrate weights, ensuring stability for entities with smaller sample sizes. These scores are linked to structured key performance indicators (KPIs) to establish capability-performance mappings [6]. Analytical methods such as fixed-effects and quantile regressions, rolling-window robustness checks, and placebo tests have been conducted to identify heterogeneity and temporal dynamics. Event studies have been executed to evaluate resilience and recovery profiles in response to policy changes or disruption shocks. Governance features, including evidence linking, prompt and model version control, drift monitoring, and audit trails, have been instituted to ensure comparability, reproducibility, and regulatory compliance across different releases and jurisdictions.

## 2. Empirical Insights

### 2.1. Capability Landscape

Data governance, process intelligence, and organizational coordination are critical factors that explain significant variations across industries. These elements underpin scalable corporate social responsibility (CSR) and collaboration practices, with observable benefits extending into risk control and innovation velocity. Mature master data, end-to-end lineage, and quality service level agreements (SLAs) with clearly defined stewardship roles enhance the coupling between analytics and decision-making processes. This tight integration facilitates rapid feedback loops, improving root-cause traceability, supplier accountability, and audit readiness across multi-tier networks. Standardized data domains and contract-level identifiers enable detailed tracking of carbon emissions and labor metrics, while schema evolution policies ensure longitudinal comparability over time. The integration of pervasive process and task mining with key performance indicator (KPI)-instrumented workflows, layered automation (combining rule-based systems and machine learning), and human-in-the-loop exception handling reduces variability and shortens lead times. This approach elevates on-time-in-full (OTIF) performance and stabilizes upstream capacity planning. The use of playbooks, pattern libraries, and reusable components such as connectors, feature stores, and policy templates increases operational efficiency by promoting reuse and reducing marginal deployment costs. Cross-functional squads operating within a product-oriented model align incentives, minimize handoffs, and clarify ownership of shared services and data products, thereby enhancing reuse and reducing tool sprawl [7]. Federated enablement, supported by a central platform team, further drives adoption and streamlines operations. In highly regulated sectors, prerequisites for scalability include zero trust architectures, fine-grained access controls, and audit-ready machine learning operations (MLOps). These are complemented by robust model risk management, lineage-preserving pipelines, and privacy-by-design frameworks. Platform and cross-border businesses leverage application programming interfaces (APIs), partner marketplaces, and shared data products to amplify network effects. This accelerates partner onboarding and co-

innovation through standardized contracts and transparent service levels. Capabilities broadly improved from 2019 to 2021 due to the diffusion of cloud technologies and analytics. However, divergence emerged after 2022, driven by factors such as data localization policies, differences in artificial intelligence governance, compute price volatility, and uneven talent distribution. Industry leaders have successfully productized platforms and compliance mechanisms to build competitive advantages, codify governance into reusable modules, and achieve higher reuse ratios. In contrast, lagging organizations remain constrained by pilot projects, brittle point solutions, fragmented ownership, and limited cross-domain generalization.

### *2.2. Performance Impact*

Increases in the capability index are strongly correlated with enhanced operating margins, accelerated cash conversion cycles, and reduced safety and service incident rates [8, 9]. These benefits are particularly pronounced in areas where process intelligence minimizes rework, changeover inefficiencies, and queueing delays, and where robust data governance enhances forecasting accuracy and inventory visibility across multiple tiers. Revenue improvements are driven by refined pricing strategies, effective cross-selling, and improved customer retention, all enabled by unified customer and product views, experimentation platforms, and more reliable attribution mechanisms. In environments characterized by high complexity and stringent regulatory requirements, the use of reliable master data, traceability systems, and explainability frameworks generates higher marginal returns by mitigating compliance challenges, shortening audit durations, and facilitating exception automation with defensible controls. Operational key performance indicators typically show measurable improvements within one to three quarters as automation scales and backlogs are cleared. Profitability gains tend to compound over a 12- to 24-month period as exception rates decline, learning effects enhance model accuracy, and fixed platform costs are distributed across a broader portfolio of digitized processes. Additionally, downside risks are mitigated through fewer stockouts, improved recovery times from disruptions, enhanced supplier compliance, and reduced variance between planned and actual outcomes.

### *2.3. Heterogeneity and Moderators*

Small and medium-sized enterprises (SMEs) achieve lightweight collaboration by utilizing cloud-native and templated tools, which focus on narrow, high-return-on-investment (ROI) use cases to ensure shorter payback periods. These enterprises leverage managed services, prebuilt connectors, and low-code automation to bypass complex integration processes while maintaining robust evidence trails for audits. For asset-heavy firms, the initial step should involve unifying operational technology (OT) data and adopting event-driven architectures. This foundation enables the scaling of predictive maintenance and scheduling optimization through iterative validation cycles. Deploying edge gateways, time-series data lakes, and standardized telemetry schemas helps address the challenges posed by legacy protocol heterogeneity. Regulatory frameworks play a dual role as both accelerators and constraints. Clear rules and certification pathways reduce compliance uncertainty and facilitate faster scaling, whereas ambiguous or shifting requirements increase the value of pilot programs, sandboxing, and modular architectures. Ecosystem openness enhances the conversion of corporate social responsibility (CSR) initiatives into performance gains within platform businesses by fostering partner innovation and distribution. This is further supported by API monetization and shared data products, which expand the range of addressable use cases. In highly proprietary or security-sensitive environments, the maturity of security and compliance measures becomes the dominant factor influencing scalability and durability. Key elements such as zero trust, data domain tiering, and auditable machine learning operations (MLOps) determine the feasible scope and speed of rollout. Additionally, talent density and coherence in operating models act as critical moderators, shaping

learning curves, reuse rates, and the ability to sustain continuous improvement amidst evolving demand and policy landscapes.

### 3. Strategy Practice

#### 3.1. Strategy Implementation Pathway

CSR and supply chain collaboration should progress through a Diagnose--Design--Deploy--Measure--Iterate loop anchored in evidence, governance, and disciplined capital allocation, with clear ownership and timeboxed cadences to prevent pilot stagnation. Diagnosis involves leveraging advanced tools, such as large language models (LLMs), to analyze responsibility clauses and collaboration evidence, creating gap maps and uncertainty tags. These findings are normalized to domain-specific ontologies and benchmarked against industry peers to identify capability bottlenecks and policy exposures. Diagnostics are further enriched with supplier-tier heatmaps, critical-path analyses, and maturity rubrics that differentiate foundational hygiene practices from advanced, value-adding capabilities. Counterparty perspective checks are incorporated to triangulate disclosures from buyers, suppliers, and auditors, reducing one-sided bias and identifying potential greenwashing or over-commitment. Design focuses on prioritizing initiatives based on marginal return on investment and dependency graphs, while defining prerequisites such as master data readiness, access control, supplier segmentation, data-sharing agreements, and change-management enablers. Stage gates are established with clear success metrics and risk thresholds, and sequencing rules are defined to prioritize data and access prerequisites, followed by narrow-scope pilot projects, and then scaling through standardized templates. Financing structures, including co-investment with tier-1 suppliers, outcome-based contracts, and blended finance for decarbonization, are integrated to align economic incentives with responsibility objectives. Deployment emphasizes the delivery of shared data products and responsibility contract templates, advancing vendor-managed inventory (VMI), collaborative planning, forecasting, and replenishment (CPFR), and green procurement pilots with clearly defined entry and exit criteria. Audit-ready machine learning operations (MLOps), model risk management, and zero-trust frameworks are introduced to ensure scalable compliance. Rollout strategies prioritize lighthouse sites, federated enablement, and reusable integration kits to accelerate time-to-value, while change networks, champion programs, and embedded training initiatives enhance adoption and minimize shadow processes. Interoperability and resilience are supported through the use of canonical APIs, schema registries, and test suites, while privacy and export-control rules are codified into policy-as-code to ensure consistent enforcement across jurisdictions.

Measurement connects objectives and key results (OKRs) to cost, risk, and revenue levers, employing causal evaluation methods such as A/B testing, stepped-wedge designs, or synthetic controls. Processes are instrumented with service level objective (SLO) and service level agreement (SLA) monitoring, lineage tracking, and policy controls to ensure traceability and accountability. The measurement framework is extended to include benefit-realization tracking, distinguishing between cashable and non-cashable benefits, as well as metrics for learning velocity, which measure the cycle time from insight to actionable change. Fairness and compliance indicators, such as supplier inclusion, grievance resolution, and model bias audits, are also incorporated. Governance cadences are established, including monthly value reviews, quarterly portfolio councils, and semiannual external assurance processes, to validate attribution, update weighting criteria, and phase out underperforming initiatives. Iteration involves monitoring for drift in data, models, and processes, maintaining technical debt registers, and applying decommissioning rules. Portfolio budgeting strategies, such as "scaling winners and cutting losses," are employed to optimize capital allocation. Lessons learned are fed into updates for taxonomies, vendor strategies, and operating model refinements. Rollback playbooks and blue/green deployment strategies are embedded to minimize disruptions during upgrades, while post-mortems and win reviews are systematically documented in

pattern libraries. Momentum is sustained through incentive alignment, such as linking leadership bonuses to verified CSR and collaboration outcomes, and through the use of transparent dashboards accessible to partners. These dashboards foster reputational reinforcement and create peer pressure to achieve higher standards of responsibility and collaboration.

### *3.2. Managerial Recommendations*

Adopt the principle of "responsibility is data" to enhance traceability, carbon accounting, and labor transparency. This approach enables the establishment of a reliable master data foundation with quality service-level agreements (SLAs), auditable evidence trails, standardized identifiers, and tamper-evident logs. Integrating digital product passports and chain-of-custody markers can further extend visibility across multiple supply chain tiers. Embed corporate social responsibility (CSR) into sales and operations planning (S&OP) and supplier performance management by utilizing gain-sharing and value-sharing mechanisms. These mechanisms foster stronger collaboration, align incentives related to service, cost, and emissions, and codify obligations into smart templates that automate compliance checks and dynamically adjust penalties or credits based on verified outcomes. Establish cross-functional product organizations and create a joint innovation fund supported by standardized interfaces, reference architectures, and pattern libraries to accelerate reuse and diffusion. Vendor-neutral governance should be instituted to prevent lock-in and ensure interoperability, complemented by a partner accreditation program that certifies readiness based on data, security, and sustainability criteria. In highly regulated industries, compliance processes should be "productized" with auditable workflows and model risk management to streamline audits and enable scalability. This can be achieved through domain-tiering, least-privilege controls, data minimization, and privacy-by-design principles, which collectively reduce compliance costs. Additionally, training programs, playbooks, and readiness checklists should be implemented to sustain adoption, while pre-negotiated regulator sandboxes can facilitate controlled experimentation. Workforce capabilities can be reinforced through role-specific curricula for planners, buyers, and data stewards, as well as through community-of-practice forums that promote knowledge sharing across business units and partners.

### *3.3. Risks and Safeguards*

Establishing three lines of defense across strategy, operations, and technology is essential for maintaining collaboration and compliance as scale increases. Strategically, organizations should conduct scenario exercises and develop emergency plans with clearly defined exit and termination criteria. Stress-testing supplier concentration, policy changes, cyber extortion risks, and climate-related events is crucial, alongside predefining contingency capital buffers and governance escalation pathways. Incorporating option valuation can help optimize the timing of expansions under uncertain conditions. Operationally, dual sourcing, buffer inventories, and joint insurance arrangements can mitigate the risks of disruption. Time-phased inventory strategies and dynamic safety-stock policies should be implemented to enhance resilience [10–12]. Codifying joint incident response protocols with suppliers can accelerate recovery and minimize deviations between planned and actual outcomes. Early-warning signals, such as lead-time fluctuations, defect surges, and ESG audit inconsistencies, should be monitored to activate predefined response playbooks. Technologically, organizations must bolster security and accountability through zero trust frameworks, confidential computing, and explainable AI. Continuous monitoring, drift alerts, canary releases, and rollback mechanisms should be supported by red-team testing and breach simulations to validate controls. Data domain tiering, data loss prevention measures, and hardware root-of-trust protocols should be enforced at critical nodes. Supplier tiering and continuous auditing can prevent tool proliferation and standard deviations, while compliance gateways for cross-border data flows ensure robust performance under shifting regulatory and market

conditions. Residual risks should be tracked using key risk indicators tied to capital at risk and recovery time objectives. Maintaining a dynamic risk register aligned with portfolio decision gates ensures that scaling decisions remain evidence-based and reversible.

#### **4. Strategic Expansion**

##### *4.1. Capital and Resource Allocation Strategy*

A barbell strategy combining "durable core" and "high-beta options" has been adopted to optimize capital and resource allocation. This approach ensures sustained investment in low-volatility foundations such as data governance, master data management, and observability, while simultaneously enabling flexible funding for high-risk, high-reward initiatives like collaborative projects and green innovation. To maintain control and minimize risks, stage gates, exit clauses, and value-based milestones are implemented, ensuring that pacing is regulated, downside risks are capped, and validated learning is incentivized. Funding is released in tranches, contingent upon the reduction of risks and improvements in unit economics. Shared services and data products are platformized to enhance reusability, accelerate time-to-value, and lower marginal costs, with chargeback and showback models employed to encourage disciplined consumption. Co-investment vehicles, gain-sharing contracts, and outcome-based pricing mechanisms are leveraged to maximize capital efficiency and align incentives with suppliers and ecosystem partners. Vendor diversification strategies are prioritized to mitigate risks such as lock-in and compute price volatility. Additionally, resilience capital is allocated for redundant data paths, compliance automation, and model risk reserves, guided by scenario-based budgeting that accounts for macroeconomic, policy, and supply chain disruptions [13–15].

##### *4.2. Supply Chain Collaboration Advancement Strategy*

The strategy emphasizes joint planning and forecasting processes, such as sales and operations planning and integrated business planning, which are extended progressively to collaborative replenishment models like vendor-managed inventory and collaborative planning, forecasting, and replenishment. It incorporates co-production initiatives and joint risk management efforts, supported by cross-firm metric alignment and transparent dashboards tailored to specific roles. Shared calendars, visibility into constraints, and exception playbooks are implemented to synchronize demand and supply signals effectively. Green procurement catalogs and low-carbon standards are operationalized to guide sourcing decisions and foster supplier development. Joint drills, tabletop exercises, and mutual-aid agreements for critical materials and high-risk nodes are conducted, complemented by pre-negotiated surge clauses and recovery service level agreements. In cross-border and platform contexts, partner onboarding is expedited through standardized APIs, trusted data-sharing frameworks, and compliance gateways that ensure adherence to data residency and transfer regulations. Federated analytics are utilized to safeguard intellectual property while deriving insights at the network level. Interoperability standards and certification pathways are embedded to reduce time-to-value and enhance partner engagement.

##### *4.3. Performance Measurement and Continuous Improvement Strategy*

An indicator tree has been constructed to encompass environmental, social, governance, and resilience dimensions. This framework connects leading indicators—such as data quality service level agreements (SLAs), collaboration coverage, pilot pass rates, and supplier audit closure times—with lagging indicators, including margin, cash conversion, incident rates, and on-time-in-full (OTIF) performance. These metrics are managed using rolling baselines, quantile targets, and control limits to ensure robust performance tracking. A causal evaluation stack has been implemented, incorporating experimentation platforms like A/B testing, stepped-wedge designs, and synthetic controls, alongside quasi-experimental designs for non-random rollouts. This approach

ensures a comprehensive evidence chain through evidence-linked logs and lineage. Telemetry and service level objectives (SLOs) are deployed across process, model, and data-product layers to enable real-time health monitoring, drift detection, and alerting. Scorecard cadences are enforced to align metric movements with resource reallocations and incentive structures [16, 17]. Feedback loops are established to refine metric weights, adjust thresholds, and reprioritize roadmaps. Automated post-mortems and win reviews are codified into pattern libraries, fostering continuous improvement while maintaining historical comparability across different releases and jurisdictions.

## 5. Conclusions

Corporate Social Responsibility (CSR) enhances Environmental, Social, and Governance (ESG) outcomes and operational resilience through three interconnected mechanisms: information symmetry, risk sharing, and co-innovation. Information symmetry reduces coordination costs and forecast errors, enabling more efficient decision-making. Risk sharing mitigates the impact of disruptions by compressing disruption tails, fostering stability in operations. Co-innovation accelerates the adoption and diffusion of sustainable processes and products, driving long-term environmental and operational benefits. These mechanisms are mediated by collaborative capabilities across data management, process optimization, and organizational alignment. Amplifiers such as robust data governance, advanced process intelligence, and ecosystem openness, alongside thresholds like security and compliance maturity, collectively influence the scale, speed, and sustainability of these benefits. Evidence suggests measurable improvements in key performance indicators (KPIs) within the near term, with compounding benefits over 12 to 24 months as automation, traceability, and partner alignment deepen. Future research should focus on expanding multilingual and multi-industry analyses to address disclosure variability, enhancing causal identification through experimental designs and natural shocks, and refining benchmarks tailored to small and medium enterprises (SMEs) and highly regulated industries. Key priorities include developing standardized taxonomies, creating auditable measurement pipelines, and conducting portability tests to strengthen the connection between capability scores, capital allocation, and long-term strategic value creation.

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