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Supply Base Complexity and Firm Profitability

The Role of Sustainability Visibility in Monitoring Supplier Performance and Financial Outcomes

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Abstract

This study examines the relationship between supply base complexity, sustainability visibility, and firm profitability in global Fortune 100 companies. Drawing on Information Processing Theory, Contingency Theory, and the Relational View, the research explores whether having a complex supplier base directly harms financial performance and whether firms' ability to monitor supplier sustainability performance influences this relationship.

Using a quantitative research approach, the study analyzes secondary data from the Refinitiv (LSEG) Workspace database for 94 Fortune 100 firms over the period 2021–2023. The proposed relationships are tested using hierarchical regression analysis.

The results challenge several common assumptions in the literature. First, supply base complexity does not show a direct negative relationship with profitability. Instead, firms with more complex supplier networks tend to exhibit higher levels of sustainability visibility. Second, sustainability visibility has a strong and positive direct association with profitability, independent of supply base complexity. The expected moderating effect of sustainability visibility on the complexity–profitability relationship is not supported.

Overall, the findings suggest that sustainability visibility operates as an independent strategic capability rather than as a conditional buffer against complexity. Complex supply networks appear to motivate firms to develop stronger visibility systems, and these systems are associated with improved financial performance. This study therefore positions sustainability visibility as a value-creating capability that supports effective management of complex global supply chains.

Keywords Supply Base Complexity, Sustainability Visibility, Transparency, Profitability, Dynamic Capabilities, Supply Chain Management, ESG

Preface and acknowledgements

This master's thesis was conducted as part of the Master's Programme in Business Analytics. The research reflects my academic interests in supply chain management, sustainability, and data-driven analysis, and it represents the final requirement for the completion of my degree.

I would like to express my sincere gratitude to my thesis supervisor, Professor Seongtae (Seo) Kim, for his exceptional patience, continuous guidance, and constructive feedback throughout the thesis process. His understanding, encouragement, and thoughtful advice were invaluable in shaping and improving this work.

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Ha Do

Table of Contents

Chapter 1: Introduction

1. Background and Motivation

Over the past two decades, globalization and digitalization have significantly changed the structure of global supply chains. Firms increasingly depend on large, geographically dispersed, and multi-tier supplier networks to reduce costs, access specialized knowledge, and improve operational flexibility (Choi & Krause, 2006; Bode & Wagner, 2015). While these extended networks offer strategic benefits, they also introduce high levels of supply base complexity. This complexity arises from a growing number of suppliers, greater diversity among them, and stronger interconnections across tiers, which make coordination, monitoring, and control more difficult (Bozarth et al., 2009; Serdarasan, 2013).

As supply networks become more complex, firms face increasing challenges in maintaining visibility beyond their first-tier suppliers. Information asymmetries and limited transparency in upstream tiers make it difficult to monitor supplier behavior and manage risks effectively (Tachizawa & Wong, 2014; Wilhelm et al., 2016). These challenges are particularly critical in relation to sustainability issues, where environmental and social risks often occur deep within the supply chain.

At the same time, sustainability has evolved from a peripheral concern into a central strategic issue in supply chain management. Firms are now under growing pressure from regulators, investors, consumers, and civil society to take responsibility for sustainability practices across their entire supply networks (Busse et al., 2017; Yawar & Seuring, 2017). In response, firms increasingly invest in sustainability visibility, defined as the organizational capability to access, process, and use sustainability-related information across multiple supply chain tiers (Gualandris et al., 2015).

Sustainability visibility enables firms to identify risks earlier, engage more effectively with suppliers, and meet expanding environmental, social, and governance (ESG) reporting requirements (Marshall et al., 2016; Villena & Gioia, 2020). Despite its growing importance, however, the role of sustainability visibility in shaping the performance implications of supply base complexity remains insufficiently understood. This study addresses this gap by examining how supply base complexity, sustainability visibility, and firm profitability are related in the context of Fortune 100 firms

2. Research Gaps

2.1. Ambiguity in the Complexity–Performance Relationship

The literature provides conflicting explanations regarding how supply base complexity affects firm performance (Kim et al.,2025). From an Information Processing Theory perspective, complexity increases information overload, coordination difficulties, and decision-making costs, which may reduce profitability (Galbraith, 1974; Bozarth et al., 2009; Bode & Wagner, 2015). Similarly, Transaction Cost Economics suggests that complexity raises monitoring and governance costs.

In contrast, the Resource-Based View and the Relational View argue that a large and diverse supplier base can enhance innovation, resilience, and strategic flexibility, potentially improving firm performance (Barney, 1991; Dyer & Singh, 1998; Dubey et al., 2021). These opposing views suggest that the impact of complexity on profitability is likely contingent on organizational capabilities. However, empirical studies that explicitly test such contingent effects using recent, large-scale data remain limited (Ates et al., 2020).

2.2. Limited Measurement of Sustainability Visibility

Although supply chain visibility is widely discussed in logistics and operations literature, sustainability visibility is still underdeveloped conceptually and empirically. Many studies rely on narrow indicators, such as the existence of supplier codes of conduct, rather than capturing visibility as a broader organizational capability (Busse et al., 2017). The Two-Pillars Framewor, which distinguishing between information availability and information accessibility, offers a comprehensive conceptual foundation but has rarely been operationalized in quantitative, large-sample research (Gualandris et al., 2015; Köhler & Pizzol, 2020). As a result, there is a lack of validated measures that reflect the depth and breadth of sustainability visibility practices across firms.

2.3. Unclear Role of Sustainability Visibility in the Complexity–Profitability Link

The literature suggests two possible roles for sustainability visibility. First, visibility may act as a moderator by reducing the negative effects of complexity through improved information processing and coordination (Wiengarten et al., 2019). Second, visibility may function as a mediator, where complexity drives firms to invest in visibility capabilities, which then directly enhance performance (Villena & Gioia, 2020). Despite these theoretical propositions, few studies have empirically examined these mechanisms in an integrated model, leaving the interaction between complexity and visibility insufficiently understood (Hartmann & Moeller, 2014; Tachizawa & Wong, 2014).

2.4. Lack of Contemporary, Large-Scale Evidence

Most existing empirical studies rely on case studies, small surveys, or older datasets that do not fully reflect the current supply chain environment shaped by post-pandemic disruptions, increased ESG regulation, and rapid digitalization (Ivanov, 2020; Queiroz et al., 2022). There is a clear need for research using recent, standardized data from large multinational firms that are both highly exposed to supply chain complexity and actively investing in sustainability visibility.

2.5. Synthesis of the Research Gap

In summary, the literature lacks an integrated empirical framework that (1) uses a theory-based and comprehensive measure of sustainability visibility, (2) examines whether sustainability visibility moderates or mediates the relationship between supply base complexity and profitability, and (3) applies recent data from large, complex organizations.

This study addresses these gaps by empirically investigating the relationships between supply base complexity, sustainability visibility, and firm profitability, thereby contributing to both theory development and managerial practice.

3. Research Questions

Building on the theoretical and practical motivations discussed above, this study examines how firms manage increasingly complex supply bases in the context of rising sustainability expectations. In particular, it focuses on the role of sustainability visibility as an organizational capability that supports supplier monitoring and potentially influences firm performance. To address these objectives, the study is guided by the following research questions.

The first research question examines the direct performance implications of sustainability visibility:

> **RQ1: How does supply base complexity affect firm profitability?**

This research question examines how the structure of modern global supply bases relates to firm profitability. As firms work with a larger, more diverse, and more geographically dispersed set of suppliers, they face higher coordination costs, greater uncertainty, and increased risk. However, complex supply bases may also provide benefits, such as access to specialized capabilities, flexibility in sourcing, and opportunities for innovation. The question therefore asks whether the disadvantages of managing a complex supplier network are greater than the advantages it can create, or whether complexity can instead support better financial performance. In this way, the study seeks to determine whether supply base complexity acts mainly as a source of value or as a constraint on profitability.

The second research question integrates the previous two by examining the role of sustainability visibility in the complexity–performance relationship:

> **RQ2: What is the role of sustainability visibility in the relationship between supply base complexity and firm profitability?**

This research question asks whether sustainability visibility, the ability to track and understand environmental and social practices across suppliers, changes how supply base complexity affects firm profitability. A complex supply network can hurt profits due to hidden risks and inefficiencies. Sustainability visibility may reduce these downsides by letting firms monitor, control, and add value across their supply chain, thus turning complexity from a cost into a strategic advantage. The study essentially tests if seeing more leads to earning more, even when the supply base is large and varied.

Taken together, these research questions advance supply chain theory by conceptualizing sustainability visibility as a strategic organizational capability. From a managerial perspective, they clarify whether investments in supplier sustainability monitoring are primarily reactive responses to complexity or proactive initiatives that contribute to long-term business value.

4. Structure of the Thesis

This thesis is structured into five main chapters. Chapter 1 (introduction) will present the research topic by outlining the background and motivation of the study. It identifies key research gaps in the existing literature, presents the research questions, and explains the overall structure of the thesis. Chapter 2 (Literature Review and Development of Hypotheses) provides a comprehensive review of prior research on supply chain complexity, with a particular focus on supply base complexity from structural and dynamic perspectives. It introduces the main theoretical lenses used in this study, including Information Processing Theory, Contingency Theory, and the Relational View. The chapter also reviews the concept of sustainability visibility, discusses challenges related to multi-tier supply chains, and develops the hypotheses and conceptual framework that guide the empirical analysis. Chapter 3 (Methodology) outlines the research design and methodological approach. It describes the data collection process, sampling frame, and time period covered by the study. The chapter also explains how key variables, ncluding supply base complexity, sustainability visibility, and firm profitability, are operationalized, and presents the analytical methods used to test the hypotheses. Chapter 4 (Analysis and Results) will report the empirical findings of the study. It begins with descriptive and correlation analyses to provide an overview of the data, followed by regression analyses used to test the proposed hypotheses. The chapter presents both the main results and additional post hoc findings related to the direct effects of sustainability visibility. Finally, Chapter 5 (Discussion and Conclusion) interprets the empirical findings in relation to the research questions and theoretical framework. It summarizes the key insights, discusses the theoretical and managerial contributions of the study, and acknowledges its limitations. The chapter concludes by suggesting directions for future research on supply base complexity, sustainability visibility, and firm performance.

Chapter 2: Literature Review and Hypotheses

1. Supply Chain Complexity

1.1. Defining Supply chain complexity

Complexity, in its broadest sense, describes systems made up of many connected parts whose interactions are not always simple or predictable. Simon (1962) explains that a system is complex when it contains numerous interacting elements that behave in ways that cannot be easily understood by examining each part separately. Building on this, scholars such as Perrow (1984) and Senge (2006) emphasize that complexity has two key dimensions: its structure, which concerns how many elements a system contains and how they are arranged, and its behavior, which describes how those elements interact and change over time. In organizational studies, these ideas suggest that the more interconnected and interdependent the components of a system are, the more difficult it becomes to predict outcomes or maintain control.

This systems perspective has been widely applied to the study of supply chains, which can be viewed as large, adaptive networks of organizations, technologies, and information flows. In an increasingly globalized and interconnected business environment, firms rely heavily on external partners to source materials, components, and services. The growing dependence on outsourcing, offshoring, and strategic partnerships has transformed supply chains from relatively simple, linear structures into multi-tiered, global systems that link suppliers, manufacturers, logistics providers, and customers across multiple regions and regulatory environments (Christopher, 2016).

As a result, supply chain complexity has become a central concept for understanding modern business operations. It is often defined as the degree of difficulty involved in understanding, coordinating, and managing the multiple elements and interactions that exist within a supply network (Serdarasan, 2013; Bozarth et al., 2009). This complexity arises from both the structure of the network and the dynamic behavior of its components. The structural dimension refers to the number of entities and the variety of relationships among them, while the dynamic dimension captures the uncertainty, variability, and feedback loops that emerge as these relationships evolve over time (Bode and Wagner, 2015). Together, these two dimensions determine how challenging it is for firms to design, monitor, and control their supply chains.

1.2. Dimensions and Perspectives

While the notion of supply chain complexity has been widely examined, prior studies have approached it from different theoretical and methodological perspectives, leading to a range of proposed dimensions. Vachon and Klassen (2002) identify two major components: uncertainty, which relates to the number of elements and variability within the network, and complicatedness, which reflects the degree of interaction among those elements. Choi and Krause (2006) offer a three-dimensional view, including the number of direct suppliers, differentiation among suppliers, and relationships among suppliers, thus capturing both structural and behavioral aspects of complexity. Bozarth et al. (2009) extend this idea by classifying complexity into internal manufacturing complexity, upstream complexity, and downstream complexity, recognizing that complexity can arise from within the firm as well as across different tiers of the supply chain. Other scholars such as Serdarasan (2013) and Manuj and Sahin (2011) emphasize additional dimensions like technological, process, and decision-making complexity, arguing that the nature of complexity depends on the firm's operations and information environment. Jacobs and Swink (2011) further suggest that complexity should be understood as a multi-level construct that manifests differently at the plant, firm, and network levels.

While the concept of supply chain complexity offers a broad perspective on the challenges of managing global production and distribution networks, a significant part of this complexity originates in the supply base (Choi and Hong, 2002). The following section therefore turns to the concept of supply-base complexity, exploring how it has been defined in the literature and how it influences a firm's ability to manage supplier relationships and visibility in order to achieve sustainability and improve its own performance.

2. Supply Base Complexity

Within the broader field of supply-chain management, supply-base complexity has emerged as a critical concept for understanding how firms interact with and manage their network of suppliers. While supply-chain complexity refers to the overall intricacy of end-to-end material, information, and financial flows across all tiers, supply-base complexity focuses more narrowly on the upstream part of the network. These involve different suppliers who provide inputs, components, or services to a focal firm (Choi and Krause, 2006). It captures the extent to which this supplier network is large, diverse, and interdependent, and therefore how difficult it is for the firm to coordinate, control, and maintain visibility across its operations (Bozarth et al., 2009; Bode and Wagner, 2015).

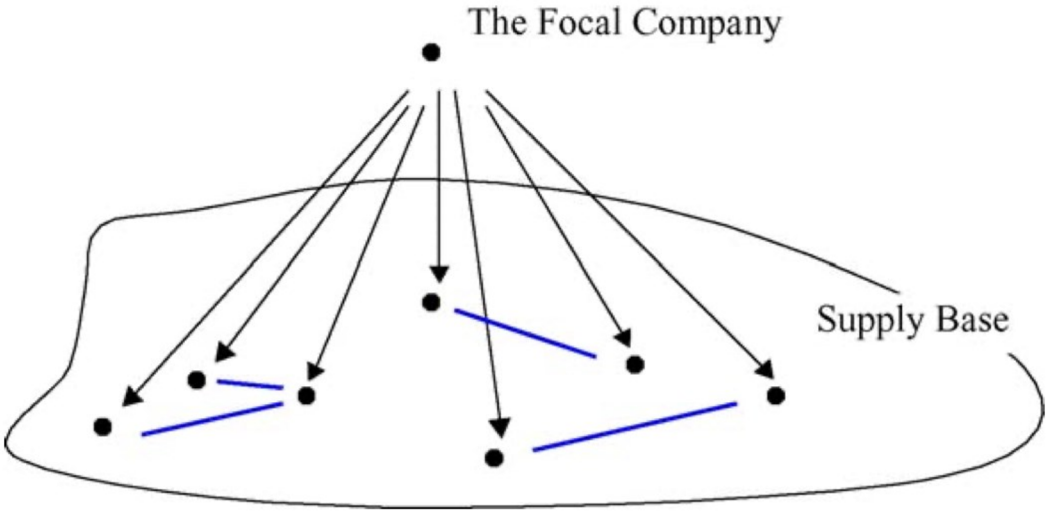

Figure 1: Focal company and its supply base (Choi and Krause, 2006)

2.1. Defining supply base complexity under structural and dynamic perspectives

2.1.1. Structual complexity in supply base

Structural complexity refers to the basic structure of a system, including how many elements it contains, how different they are, and how they are connected to one another. In systems theory, it describes how these elements are organized and how their relationships create patterns that can be difficult to understand or manage (Casti, 1979; Senge, 2006). Bozarth et al. (2009, p. 79) describe structural complexity as "the distinct number of components or parts that make up a system," while Serdarasan (2013, p. 533) defines it as the structure of the supply chain, referring to "the number and variety of its components and the strength of interactions between them." Similarly, Sterman (2000) and Waldrop (1992) point out that structural complexity increases as systems include more elements, show greater diversity, and develop stronger connections among parts. In this sense, even when individual components are simple, the way they are linked together can make the entire system complex and challenging to manage.

Applied to supply base context, structural complexity represents the design or architecture of a firm's supplier network. It is shaped by three main features: supplier numerosity, supplier heterogeneity, and supplier interconnectedness (Choi and Krause, 2006; Serdarasan, 2013). First, supplier numerosity (also known as horizontal complexity) refers to how many suppliers a firm works with at the same time. A larger supplier base usually increases the number of transactions, communication flows, and monitoring tasks that must be handled (Choi and Krause, 2006; Milgate, 2001). For example, a global electronics company may source similar components from dozens of suppliers in Asia, Europe, and North America to reduce dependence on any single source and to maintain cost competitiveness. This wide coverage improves flexibility and risk diversification but also raises the workload for procurement managers, who must monitor performance, coordinate logistics, and integrate sustainability data from many partners (Bozarth et al., 2009; Bode and Wagner, 2015). In contrast, a smaller supplier base simplifies coordination but increases the firm's exposure to disruptions if one supplier fails. Thus, numerosity reflects a trade-off between risk mitigation through multiple sourcing and the administrative effort required to manage numerous relationships. Second, supplier interconnectedness (also known as vertical complexity) refers to the degree of dependence and interaction among suppliers themselves (Choi and Hong, 2002; Pathak et al., 2007). In complex, multi-tier networks, suppliers often share sub-suppliers or collaborate through partnerships, joint ventures, or shared logistics systems. These linkages can enhance efficiency and knowledge transfer but also create channels through which disruptions or non-compliance can spread. For example, if a second-tier supplier providing raw materials faces an environmental violation, the reputational and operational effects can ripple across several first-tier suppliers and ultimately reach the focal firm (Bode and Wagner, 2015; Tachizawa and Wong, 2014). Interconnectedness therefore magnifies both the opportunities for collaboration and the risks of cascading failure. And finally, supplier heterogeneity captures how different suppliers are from one another in terms of geography, ownership, technology, culture, and capabilities (Lu and Shang, 2017; Chae, 2013). For instance, an automobile manufacturer may buy parts from large multinational corporations for core components and from smaller local suppliers for customized items. This diversity provides access to unique expertise and innovation but makes it harder to align quality, cost, and sustainability standards across the network (Dubey et al., 2021). Differences in languages, time zones, and regulatory contexts can also create communication barriers and inconsistencies in data collection and reporting (Koberg and Longoni, 2019). Consequently, while supplier heterogeneity can strengthen competitiveness and flexibility, it also increases uncertainty and coordination challenges.

In general, structural complexity can be seen as both a source of strength and a potential challenge. On one hand, a broad and diverse supplier network can improve innovation, flexibility, and risk management (Choi and Krause, 2006; Dubey et al., 2019). On the other hand, when the level of diversity and interconnection becomes too high, it can exceed managerial capacity and make it harder to control. In this way, structural complexity forms the foundation of supply-base complexity: it defines the “hardware” of the network on which dynamic interactions, uncertainty, and behavioral changes occur.

2.1.2.Dynamic Complexity in Supply Base

While structural complexity focuses on the fixed configuration of the supply base, dynamic complexity emphasizes how this structure evolves and behaves over time. It refers to the uncertainty, variability, and feedback that arise as suppliers, markets, and technologies interact in unpredictable ways. In systems theory, dynamic complexity captures how small changes in one part of a system can create large and often unexpected effects elsewhere, making outcomes difficult to predict even when the system’s structure is known (Sterman, 2000; Senge, 2006). Bozarth et al. (2009) describe dynamic complexity as “the unpredictability of a system’s response to a given set of inputs,” while Serdarasan (2013) defines it as the uncertainty within the supply chain involving time delays, randomness, and shifting relationships. In essence, dynamic complexity reflects the behavioral and temporal dimension of supply networks: the way they change, react, and adapt over time.

In supply base context, dynamic complexity emerges from three main source: continuous changes in supplier relationships, continuous change in market conditions, and continuous change in operational processes (Bode and Wagner, 2015; Serdarasan, 2013; Manuj and Sahin, 2011; Pathak et al., 2007; Ivanov, 2020).

The first major source of dynamic complexity arises from the continuous changes in supplier relationship. In global supply bases, relationships rarely remain static. Suppliers frequently enter or exit the network, modify their production capacity, or shift strategic priorities, requiring firms to continuously adjust their sourcing and coordination activities (Bode and Wagner, 2015; Zhao et al., 2022). These changes are often accompanied by a shift from transactional relationships toward more strategic, long-term partnerships centered on collaboration, innovation, and sustainability (Choi and Krause, 2006; Koberg and Longoni, 2019). Such transitions create new dependencies and increase the amount of information that firms must process to maintain alignment and trust across multiple tiers (Tachizawa and Wong, 2014). Moreover, because suppliers themselves are embedded in multi-tiered networks, disruptions or compliance failures at lower tiers can cascade upward, amplifying uncertainty at the focal firm level (Villena and Gioia, 2020). As Pathak et al. (2007) note, supply networks function as complex adaptive systems which means changes in one relationship can trigger feedback loops that reshape behaviors across the entire system. Therefore, as supplier relationships become more fluid and interconnected, they add volatility and unpredictability to the supply base.

A second source of dynamic complexity stems from the changes in global market conditions. Supply chains today operate within an environment characterized by fluctuating customer demand, evolving trade regulations, geopolitical instability, and macroeconomic uncertainty (Manuj and Sahin, 2011; Chae, 2013). Market disruptions such as economic crises, natural disasters, and the COVID-19 pandemic have demonstrated how quickly these factors can destabilize supply networks and disrupt established coordination mechanisms (Ivanov, 2020; Ketchen and Craighead, 2021). Furthermore, the increasing emphasis on sustainability and circular economy principles requires firms to adapt to evolving environmental and social standards, often on short notice (Yawar and Seuring, 2017; Koberg and Longoni, 2019). For example, shifts in consumer demand toward ethical sourcing and low-carbon materials have forced companies to reconfigure supplier portfolios and compliance systems in industries such as electronics and apparel. These dynamic market forces interact closely with relational changes, reinforcing uncertainty and compelling firms to develop greater flexibility and real-time responsiveness.

A third and closely related source of dynamic complexity arises from continuous changes in operational processes within and across suppliers. As technologies, production methods, and quality systems evolve, firms must regularly adjust coordination mechanisms and information systems to maintain performance consistency (Serdarasan, 2013; Bozarth et al., 2009). The growing adoption of automation, blockchain, and artificial intelligence has undoubtedly improved efficiency and traceability, yet it has also introduced new coordination challenges when suppliers differ in digital maturity or technological compatibility (Bag et al., 2021; Queiroz et al., 2022). For instance, real-time monitoring tools may enhance visibility for advanced suppliers but create data inconsistencies when smaller firms lack integration capacity. In addition, process variability, such as differences in lead times, quality standards, or production capabilities, can generate ripple effects that spread through the network, creating further instability (Bode and Wagner, 2015). Moreover, as Ates et al. (2020) point out, evolving operational linkages make it increasingly difficult for firms to ensure consistent sustainability oversight across the supply base. Together, these operational, relational, and market changes reinforce one another, forming feedback loops that amplify uncertainty and make dynamic complexity an inherent characteristic of modern supply base management.

From a managerial perspective, dynamic complexity creates persistent challenges in coordination, forecasting, and control. The constant shifts in supplier performance, production capacity, and technological development make it difficult for managers to maintain accurate information and make timely decisions (Manuj and Sahin, 2011). Because conditions change so rapidly, even well-designed monitoring or planning systems may become outdated before new data can be fully analyzed.

2.1.3. Interaction Between Structural and Dynamic Complexity

Although structural and dynamic complexity are conceptually distinct, in practice they are deeply interdependent. Structural complexity reflects the configuration of a firm's supply base while dynamic complexity concerns the changes, feedback loops, and uncertainties that arise from interactions among those elements over time. The configuration of a supply base shapes its potential for dynamic behavior: as the network becomes larger and more diverse, the number of possible interactions and feedback effects increases exponentially, making behavior less predictable (Bozarth et al., 2009; Turner et al., 2018). For instance, a firm coordinating multiple suppliers across regions and technologies may experience amplified disruptions when small fluctuations in demand or logistics propagate through its interconnected network (Chae, 2013; Wilding, 1998).

At the same time, dynamic complexity feeds back into the structure of the supply base. Over time, supplier turnover, strategic re-sourcing, technological innovation, and policy shifts modify how suppliers are linked to the focal firm and to one another (Serdarasan, 2013; Ates et al., 2020). These continuous adjustments can reshape the topology of the network, creating new dependencies or dissolving existing ones (Bozutti and Esposto, 2019). For example, when firms adopt digital platforms or sustainability requirements, they often restructure their supplier portfolios, leading to new patterns of collaboration, data sharing, and risk exposure (Dubey et al., 2019; Chowdhury and Quaddus, 2017). Hence, the supply base evolves as a self-organizing system, in which structural characteristics and dynamic behaviors co-evolve through feedback and adaptation (Pathak et al., 2007; Surana et al., 2005).

This interaction suggests that supply base complexity should be understood not as a static condition but as an emergent property of ongoing change. Structural complexity amplifies the effects of dynamic fluctuations by increasing interdependencies, while dynamic shifts continuously reshape the structure itself (Bode and Wagner, 2015; Ivanov, 2020). As a result, the combined effect is nonlinear: minor changes in one part of the network can generate disproportionate consequences elsewhere, creating unpredictability and management challenges (Manuj and Sahin, 2011; Bozutti and Esposto, 2019). Recognizing this reciprocal relationship highlights that effective management of supply base complexity requires understanding how static and dynamic elements interact, rather than treating them in isolation.

2.2. Theoretical Lenses for Understanding Organizational Implications of Supply Base Complexity

Understanding supply base complexity benefits from the use of several theoretical perspectives that help explain how organizations experience and manage uncertainty in their supplier networks. Although supply base complexity encompasses both structural and dynamic dimensions, its organizational implications can be more effectively interpreted through three complementary lenses: Information Processing Theory (Galbraith, 1974), Contingency Theory (Donaldson, 2001; Ates et al., 2020), and the Relational View (Dyer and Singh, 1998). Together, these perspectives provide insight into how firms interpret, coordinate, and respond to the challenges that arise from managing diverse and interdependent suppliers.

2.2.1.Information Processing Theory

Information Processing Theory (IPT) provides a foundational lens for understanding how organizations manage the informational challenges created by complex supplier networks. The theory posits that organizations must align their information-processing capacity with the amount of uncertainty and information load generated by their environment (Galbraith, 1974; Tushman and Nadler, 1978). In the context of a complex supply base, firms must process large volumes of supplier-related data, including performance metrics, compliance records, and inter-supplier dependencies (Bozarth et al., 2009; Bode and Wagner, 2015).

As supplier networks expand in size and diversity, the informational demands placed on firms increase significantly. The integration of multiple suppliers across tiers and regions makes it harder to interpret and coordinate supplier information consistently (Choi and Krause, 2006; Serdarasan, 2013). When a firm's information-processing systems, such as monitoring routines, coordination structures, and IT infrastructure, fail to match these growing demands, it leads to inefficiencies, slower decision-making, and reduced responsiveness (Turner et al., 2018; Manuj and Sahin, 2011).

Modern research extends IPT to explain how digital technologies and analytics tools enhance firms' information-processing capacity. Digital integration allows for real-time data sharing and transparency across the supply base, thereby mitigating the negative effects of complexity (Luo and Yu, 2022; Queiroz et al., 2022). Thus, IPT provides a conceptual foundation for understanding how firms design their internal systems to balance the informational demands of managing a complex and evolving supplier network.

2.2.2. Contingency Theory

Contingency Theory complements IPT by emphasizing fit - the alignment between a firm's internal structures and its external environment. It argues that there is no universally optimal structure; rather, the effectiveness of an organization depends on how well its design fits the complexity and uncertainty of its surroundings (Donaldson, 2001).

Applied to the supply base, this theory suggests that firms must tailor their governance mechanisms and coordination structures to the characteristics of their supplier networks. For instance, a firm with a small, geographically concentrated supplier base may perform well with centralized decision-making and formal control systems. In contrast, a firm managing a large, global, and technologically diverse base may require decentralized structures, flexible communication routines, and adaptive contracting mechanisms (Ates et al., 2020; Chae, 2013; Zhao et al., 2022).

Contingency Theory also highlights that misalignment, such as using rigid monitoring procedures in a highly dynamic supplier environment, can lead to inefficiency, conflict, and reduced performance (Milgate, 2001; Ketchen and Craighead, 2021). Moreover, environmental contingencies such as digital maturity, regulatory pressure, and supply chain turbulence can influence the optimal governance mode (Fisher, 1997; Ivanov, 2020). Hence, the theory reinforces that effective supply-base management requires continuous structural adaptation to maintain alignment with evolving supplier and market conditions.

2.2.3. Relational view

The Relational View extends the understanding of supply base complexity beyond the focal firm, emphasizing that competitive advantage can arise from inter-firm relationships and joint capabilities (Dyer and Singh, 1998). In a complex supplier base characterized by interdependence, uncertainty, and frequent change, close collaboration with key suppliers can mitigate risks and enhance performance.

Relational mechanisms such as trust, transparency, and joint problem-solving help firms cope with the informational overload and coordination challenges inherent in complex supplier networks (Choi and Krause, 2006; Koberg and Longoni, 2019). These mechanisms allow for faster knowledge sharing, mutual adaptation, and improved responsiveness to disruptions (Dubey et al., 2019; Villena and Gioia, 2020). For example, collaborative partnerships can improve visibility across multi-tier networks, enabling proactive responses to quality issues or environmental risks (Hartmann and Moeller, 2014; Yawar and Seuring, 2017).

In this sense, the Relational View reframes supply-base complexity not only as a source of difficulty but also as an opportunity to create relational rents which is value derived from cooperation, joint investments, and shared learning among firms and suppliers (Dyer and Singh, 1998; Wong et al., 2015). By developing trust-based relationships, firms can transform the potential burden of managing numerous suppliers into a strategic resource for innovation and resilience.

3. Sustainability visibility in supply base

3.1. Defining Sustainability Visibility

3.1.1. Sustainability Visibility

Sustainability has become a central concern in contemporary supply chain management as firms face increasing expectations from regulators, investors, consumers, and society to operate more responsibly (Epstein and Buhovac, 2014; Crane et al., 2008). Whereas supply chains were once designed primarily around cost efficiency, responsiveness, and risk minimization (Christopher, 2016; Fisher, 1997), the twenty-first century has brought a broader orientation toward environmental stewardship, social responsibility, and governance accountability (Carter and Rogers, 2008; Sarkis et al., 2011). These changes reflect both external pressures from stakeholders (Freeman, 1984; Klassen and Vereecke, 2012) and firms' internal recognition that sustainability-related risks, such as greenhouse gas emissions, biodiversity loss, labor violations, and corruption, can jeopardize long-term performance and corporate legitimacy (Seuring, 2013; Hofmann et al., 2015; Yawar and Seuring, 2017). Within this shifting landscape, visibility has emerged as essential capabilities: without reliable insight into upstream practices, firms cannot ensure that sustainability goals are met or credibly report performance to stakeholders (Tachizawa and Wong, 2014; Busse et al., 2017; Mol, 2015).

Building on this broader context, the concept of sustainability visibility extends the traditional idea of supply chain visibility, which has typically focused on operational metrics such as inventory levels, lead times, or transportation flows (Fawcett and Waller, 2014). Sustainability visibility shifts the emphasis toward transparency in environmental, social, and governance (ESG) practices across the supply base (Busse, Schleper and Gold, 2017;

Marshall et al., 2015). This might involve access to data on carbon emissions, water use, waste management, labor conditions, health and safety, gender equality, and anti-corruption measures. Unlike operational visibility, sustainability visibility covers two types of goals. Instrumental goals focus on the business benefits of sustainability, such as reducing risks, preventing supplier misconduct, and improving operational and financial performance (Carter and Rogers, 2008; Pagell and Wu, 2009). Normative goals, by contrast, reflect ethical responsibilities, including protecting the natural environment and ensuring fair, safe, and humane working conditions across the supply base (Freeman, 1984; Crane et al., 2008). In this way, sustainability visibility addresses both what firms need to do to perform well and what they ought to do to meet societal expectations. In this way, sustainability visibility enables firms not only to improve internal decision-making but also to align their supply-chain activities with broader societal expectations of fairness, responsibility, and accountability.

3.1.2. The Two Pillars Framework for Achieving Sustainability Visibility

Researchers increasingly emphasize that the effectiveness of sustainability visibility rests on two tightly interdependent elements: information availability and information accessibility. These two components help explain why visibility remains difficult to achieve in multi-tier supply chains and clarify the organizational capabilities firms must build to transform opaque supplier networks into more transparent and accountable systems (Gualandris et al., 2015; Busse et al., 2017).

Information availability concerns whether the sustainability information needed for monitoring actually exists within the supply base and can be obtained by the focal firm. This begins with the presence of relevant environmental, social, and governance (ESG) data at the supplier level, including information on emissions, resource use, waste, labor conditions, and governance practices (Marshall et al., 2016; Hofmann et al., 2015). However, availability depends not only on the technical existence of data but also on suppliers' willingness to disclose it. Supplier transparency is shaped by relational factors such as trust, dependence, and perceived fairness (Villena and Gioia, 2020), as well as by governance mechanisms including contracts, codes of conduct, and incentives for disclosure (Hartmann and Moeller, 2014). One of the most persistent challenges arises when firms attempt to access information beyond their first-tier suppliers; sustainability risks such as labor violations, unsafe working conditions, deforestation, or illegal sourcing frequently occur in deeper tiers, where visibility is most limited (Tachizawa and Wong, 2014; Grimm et al., 2014). Furthermore, the usefulness of the information that suppliers do provide depends on its granularity. Facility-specific and process-specific data enable more accurate assessments than broad corporate-level reports (Foerstl et al., 2010). Information availability also depends on update frequency (regular, real-time, or periodic) and on data veracity, which often requires verification through third-party audits, certifications, or digital authentication systems to reduce the risk of misreporting or "greenwashing" (Meixell and Luoma, 2015; Saberi et al., 2019).

Information accessibility represents the internal counterpart to availability and refers to the extent to which firms can collect, integrate, interpret, and use the information that becomes available. This requires robust technological infrastructure, including integrated data platforms, supplier information systems, and in some cases advanced traceability tools such as blockchain, RFID, or IoT sensors (Kouhizadeh and Sarkis, 2018; Francisco and Swanson, 2018). These technologies allow firms to capture data in real time, reduce information asymmetries, and authenticate sustainability-related claims. However, technology is only one part of accessibility. Firms also require well-designed organizational processes that facilitate information sharing across departments. Sustainability-relevant data often remains siloed between procurement, compliance, quality assurance, and corporate responsibility teams, limiting its usefulness for decision-making (Wiengarten et al., 2019). To overcome this, organizations must develop coordination routines, cross-functional communication channels, and standardized reporting procedures that ensure sustainability information flows across the firm. In addition, firms need analytical and interpretive capabilities to make sense of complex ESG data. These capabilities include descriptive analytics (e.g., dashboards), diagnostic tools (e.g., supplier segmentation), and predictive assessments that help anticipate sustainability risks or identify improvement opportunities (Ben-Daya et al., 2019; Bag et al., 2021). Without such capabilities, large volumes of data may be collected but remain underutilized, limiting the impact of visibility efforts.

The interaction between information availability and accessibility is central to understanding why sustainability visibility is so challenging. Availability provides the raw material for visibility, but without internal accessibility systems, even abundant data cannot be transformed into actionable insights. At the same time, internal accessibility can stimulate improvements in availability. When suppliers observe that shared information leads to constructive engagement, clearer expectations, and enhanced collaboration, they may be more willing to disclose accurate, detailed information (Brandon-Jones et al., 2023; Villena and Gioia, 2020). This can create a positive feedback loop in which investments in accessibility encourage higher levels of supplier transparency, which in turn strengthens visibility. Over time, the interplay between these two pillars contributes to a more transparent, manageable, and resilient supply base. This reinforces prior observations in the sustainability literature that visibility is not a static condition but a dynamic capability that evolves with organizational routines, supplier relationships, and technological advancements (Mol, 2015; Busse et al., 2017).

3.2. Sustainability Visibility in Complex, Multi-tier Supply Chains

As established in the preceding analysis of information availability, a fundamental and persistent challenge in sustainable supply chain management is the rapid decline in reliable data and oversight beyond the first tier of suppliers (Tachizawa and Wong, 2014). This phenomenon is not a marginal issue but a central structural flaw in contemporary procurement models. When firms attempt to access information upstream from their direct partners, they encounter a formidable multi-tier visibility gap: a steep drop-off in transparency that leaves the majority of the supply network obscured. This gap is critically important because academic and industry evidence consistently shows that the most severe environmental and social impacts are not typically found in final assembly factories but are embedded deeper within the chain. High-consequence risks, including systemic labor violations, unsafe working conditions, commodity-driven deforestation, and illegal sourcing, are disproportionately prevalent in these lower, less visible tiers where monitoring is most difficult and accountability is most diffuse (Wilhelm et al., 2016; Gardner et al., 2019). Consequently, a firm's sustainability performance is often only as robust as its weakest and least-known link.

3.2.1. Why It's So Hard to See Deeper into the Supply Chain

Seeing beyond your direct suppliers is difficult by design. Several built-in features of modern supply chains work together to block the view.

First, there is a hard commercial boundary that legally and operationally limits a firm's oversight. This boundary is rooted in the fundamental structure of procurement: a buyer's direct contractual relationship, and thus its formal leverage, ends with its tier 1 suppliers. There is no privity of contract with sub-suppliers, meaning the buyer has no legal standing to demand information or enforce standards beyond that first tier (Kim & Davis, 2016). From the tier 1 supplier's perspective, its own supply network is a source of competitive advantage, proprietary knowledge, and margin protection. Disclosing this list risks revealing cost structures, potentially enabling the buyer to engage in price pressure or, in a more extreme scenario, to bypass the tier 1 supplier entirely to contract directly with a cheaper source (Hartmann & Moeller, 2014). This creates a significant disincentive for transparency, as the Tier 1 supplier acts not just as a producer, but as a gatekeeper or "double agent" with divided loyalties between its buyer and its own suppliers (Wilhelm et al.,2016). Consequently, information requests about deeper tiers are often met with resistance, delays, or intentionally vague responses. Even when a Tier 1 supplier cooperates, they may only provide partial or corporate-level data that lacks the facility-specific granularity needed for true due diligence (Foerstl et al., 2010). This barrier is not merely a communication failure but a structural feature of arm's-length, transaction-focused sourcing models. It creates a perverse situation where a company can be held legally and reputationally responsible for abuses in its supply chain, yet lacks the direct contractual authority to investigate or remediate those very abuses. Overcoming this boundary requires shifting from purely transactional relationships to more collaborative, incentive-aligned partnerships where transparency is framed as a shared value-creation activity rather than a risk to the supplier's business (Villena & Gioia, 2020)

Second, the problem of limited visibility is dramatically worsened by the explosion of structural complexity in multi-tier supply chains. This is not a simple matter of adding more names to a list; it is a fundamental challenge of managing a vast, dynamic, and often informal network. The relationship is multiplicative: a single tier 1 supplier may source from numerous tier 2 component manufacturers, each of which, in turn, depends on a sprawling web of tier 3 raw material producers, such as smallholder farms, artisanal mines, or family-run workshops (Mena et al., 2013). Consequently, a company with a manageable number of direct suppliers can be indirectly linked to thousands of entities, many operating at the margins of the formal economy in geographically remote regions with limited administrative capacity (Grimm et al. 2014). This complexity is compounded by the inherent volatility and dynamism of these deeper tiers. Supply networks at this level are not static maps but fluid ecosystems. Sources change frequently due to seasonal variability, market price fluctuations, crop failure, or the collapse of small enterprises. A tier 2 factory might change to a new mineral processor or fabric mill with little notice, based solely on cost or availability (Bode & Wagner, 2015). This constant reconfiguration means any attempt to create a definitive supplier map is likely obsolete upon completion. As a result, the task transitions from a one-time mapping exercise to a need for continuous, real-time surveillance. This structural reality transforms the supply chain from a manageable pipeline into a shifting landscape, where unknown risks can emerge spontaneously from any point in the network, leaving buying firms perpetually vulnerable to disruptions and scandals originating in tiers they cannot see or control.

Third, a profound technological and data disconnect creates an insurmountable barrier to visibility. While lead firms operate on integrated digital platforms, the foundational tiers of production often function in an analog world. Business transactions at the tier 2 and 3 levels are frequently conducted via paper invoices, manual ledgers, and verbal agreements, a reality driven by cost constraints, limited infrastructure, and low digital literacy in many sourcing regions (Brennan & Tennant, 2018). This creates a critical data discontinuity: essential sustainability information, such as a farm's pesticide use, a workshop's energy consumption, or proof of wages paid, is born offline. It is trapped in physical records or local knowledge, with no digital pathway to flow upstream to corporate sustainability or procurement systems. Consequently, the gap also forces a reliance on inefficient and inconsistent monitoring methods, such as infrequent physical audits, which provide only a momentary and often unrepresentative snapshot of conditions (Meixell & Luoma, 2015). Ultimately, this technological gap doesn't merely hide information; it actively prevents the creation of a shared truth across the supply network, leaving a vacuum where claims cannot be verified and "greenwashing" can easily take root.

Finally, in high-risk sectors, opacity transitions from a passive condition to an active strategy of intentional obscuration. This is not a failure of information systems but a deliberate commercial and often illicit tactic. In markets for commodities like timber, minerals (for example, cobalt and tantalum), and agricultural products, complex chains of intermediaries exist not only to facilitate trade but also to deliberately commingle materials from certified, legal sources with those from illicit or unethical origins (Gardner, Benzie, Börner, & Dawkins, 2019). This practice, known as laundering, is designed to obscure provenance, circumvent trade sanctions or environmental regulations, and disguise the true social and environmental costs of production.

In summary, the barriers are not just random obstacles. They form a locked system: contracts stop you from asking, complexity overwhelms you, a lack of technology stops data from flowing, and, in the worst cases, people are actively lying. To see deeper, a company must find ways to break through all these barriers at once.

3.2.2. Mechanisms for Extending Visibility Across Multi-Tier Supply Chains

While the two-pillars framework explains why sustainability visibility is difficult to achieve, the question remains of how firms attempt to operationalise visibility across their supply base. In other words, information availability and accessibility describe the internal conditions that enable visibility, but organisations still require external governance approaches to access and transmit information across multi-tier networks. Therefore, the following section examines the main mechanisms firms use to extend visibility beyond their first-tier suppliers and shows how these approaches interact with the capability challenges outlined earlier.

Because sustainability risks often sit in lower levels of the supply chain, firms have started to use different mechanisms to gain visibility beyond their direct suppliers. These efforts are not only about managing one relationship, but about trying to reach multiple suppliers who are connected through long, layered networks.

One common method is cascading compliance. In this approach, firms include sustainability or transparency requirements in contracts with their first-tier suppliers, who are then expected to pass these rules on to their own suppliers (Wilhelm et al., 2016). The idea is that expectations will flow step by step across the chain. However, this mechanism becomes weaker as it moves through more layers. Each supplier may choose to share only partial information or may lack the ability to enforce requirements on their own suppliers (Mena, Humphries, and Choi, 2013). As a result, cascading compliance often fails to reach deeply into complex supply networks (Kim and Davis, 2016).

A second method is third-party monitoring and certification, such as independent audits, industry standards, or multi-stakeholder initiatives. These tools aim to provide oversight in parts of the supply chain where buying firms have little access or influence (LeBaron and Rühmkorf, 2017; Lambin et al., 2018). In practice, though, these systems mostly focus on first-tier or formal suppliers because they are easier to reach. Lower tiers, especially those in informal agricultural or mining sectors, remain poorly monitored due to limited resources, geographic remoteness, or political barriers (Huq, Stevenson, and Zorzini, 2014; Gardner et al., 2019). Thus, certification often improves transparency only where visibility is already relatively high.

More recently, firms have invested in digital traceability technologies that seek to allow product information to move across multiple supplier levels. Examples include blockchain systems, supply chain data platforms, sensor technologies, and mobile reporting tools (Kouhizadeh and Sarkis, 2018; Queiroz et al., 2022). While these tools can improve data sharing, they still depend on cooperation and accurate record-keeping at the source. If lower-tier suppliers do not create reliable data or lack the skills and incentives to use digital tools, technology cannot deliver true visibility (Brennan and Tennant, 2018).

Across all of these approaches, a similar insight appears. These mechanisms aim to address multi-tier visibility, yet they are constrained by the very structure they try to manage. They require information to move across many actors who may not want to share it or may lack the capability to do so. As a result, visibility remains uneven and highly dependent on relationship quality, institutional capacity, and the characteristics of the supply chain itself (Grimm et al.,, 2014; Villena and Gioia, 2020). This shows that improving transparency in multi-tier supply chains is not simply a matter of adopting tools, but of designing governance that can function across many connected, but independent, actors.

4. Development of Hypotheses

4.1. Supply Base Complexity and Profitability

Supply base complexity fundamentally challenges organizations, extending beyond operational coordination to directly affect financial performance. This section synthesizes three established theoretical perspectives of supply base complexity (Information Processing Theory, Contingency Theory, and the Relational View) to construct a coherent framework explaining the relationship between complex supplier networks and firm profitability. These theories operate sequentially to reveal this relationship.

4.1.1. Information Processing Theory: The Cognitive Cost of Complexity

Information Processing Theory (Galbraith, 1974) states that organizations must align their capacity to process information with the level of uncertainty in their environment. A complex supply base, characterized by numerous suppliers, multiple tiers, and intricate dependencies, produces an overwhelming volume of data related to supplier performance, logistics, and risk (Bode & Wagner, 2015). This creates a significant informational burden.

A complex supply base creates more data than a firm can process effectively. This informational overload leads directly to costly outcomes that reduce profit. According to Information Processing Theory, this mismatch causes specific financial damage through two channels.

First, it causes expensive decision-making failures. Managers make poor choices with inaccurate data. For example, they may select unreliable suppliers, leading to higher costs and quality problems. They may also forecast demand incorrectly, resulting in overstock or stockouts. These errors increase the Cost of Goods Sold (COGS) and cause lost sales (Bozarth et al., 2009; Stecke & Kumar, 2009).

Second, it forces firms to pay a "complexity tax" in buffer costs. To manage uncertainty, companies invest in costly safeguards. They hold excess inventory, which ties up capital and incurs storage fees. They also duplicate efforts, like performing redundant supplier audits. These are pure operating expenses that lower profit margins (Choi & Krause, 2006; Bode & Wagner, 2015).

These effects are not abstract. They directly increase expenses on the income statement. Higher COGS and higher SG&A (Selling, General & Administrative) expenses directly reduce a firm's operating profit (EBIT). Empirical research confirms that supply chain complexity and poor information processing are linked to lower financial performance (Hendricks & Singhal, 2005). Therefore, the cognitive burden from complexity has a straightforward and negative impact on profitability.

4.1.2. Contingency Theory: The Structural Misalignment and Its Cost

Contingency Theory explains that successful organizations align their internal structure with their external environment. According to this theory, there is no single best way to organize a firm. Performance depends on achieving a proper fit between the company's design and the specific challenges it faces (Donaldson, 2001). A complex global supply base is a major external challenge that demands a specific, adaptive internal structure to manage it well.

A common problem is structural misfit. Many companies try to control complex, sprawling supplier networks using simple and centralized organizational designs. For example, a single head office team might use standardized rules to manage hundreds of suppliers across different countries and tiers. This approach is fundamentally misaligned with the reality of a complex supply chain (Ates et al., 2020). The company's structure is not built to handle the required level of coordination and adaptation.

This misfit creates direct operational costs that lower profitability. First, it leads to poor coordination. Centralized systems cannot effectively manage real time activities across diverse locations, causing mistakes, delays, and wasted effort that raise operating expenses (Ketchen and Craighead, 2021). Second, it causes slow responses to problems. When a disruption occurs, decisions get stuck in a chain of command. This results in longer production delays and greater lost sales (Bode and Wagner, 2015). Third, it creates excessive overhead costs. Trying to monitor everything from a central point requires too many reports, audits, and managers, increasing administrative costs without improving control (Milgate, 2001).

The link to lower profitability is clear and direct. The costs from poor coordination and bloated administration increase Selling, General and Administrative expenses on the income statement. The revenue lost from slow crisis response directly reduces the top line. Together, these effects shrink profit margins. Contingency Theory also notes that achieving the right fit requires investment. A firm must invest in suitable structures, such as regional teams or better software (Fisher, 1997). Without this investment, which is often missing, the costly misfit remains. Therefore, an unmanaged complex supply base, through structural misalignment, acts as a persistent and measurable drag on a firm's profits.

4.1.3. Relational View: The Opportunity Cost of Transactional Governance

The Relational View argues that a firm's competitive advantage often comes from its relationships with other companies. Superior performance and profit are not created by a firm alone but through valuable collaboration with key partners, such as suppliers (Dyer and Singh, 1998). This collaboration generates "relational rents," which are extra profits earned jointly through cooperation, shared learning, and mutual investment. However, managing a complex supply base often works against this principle. The overwhelming difficulty of coordinating many suppliers pushes firms toward a simpler, transactional approach. They treat suppliers as interchangeable vendors governed by strict contracts, not as collaborative partners (Choi and Krause, 2006). This shift creates a major opportunity cost that directly limits profitability.

The direct link to profitability is clear because the transactional approach fails to capture value and incurs unnecessary costs. First, it forfeits relational rents. By not collaborating deeply, firms miss out on joint value creation. This includes co developing innovative products that command premium prices, jointly solving cost problems to improve margins, and making dedicated investments that improve efficiency for both parties (Dyer and Singh, 1998). These lost opportunities represent foregone revenue and unrealized cost savings, directly suppressing profit growth.

Second, this approach paradoxically increases costs. Transactional relationships are based on suspicion and short term contracts. This requires firms to spend more on continuous monitoring, frequent renegotiations, and detailed enforcement to protect their interests (Wong et al., 2015). These are pure transaction costs that add to operating expenses without creating any new value.

Third, it weakens resilience. In a transactional relationship, a supplier has little incentive to provide early warnings about potential disruptions or to go the extra mile to help during a crisis. This leaves the buying firm more vulnerable to supply shocks, which can lead to expensive emergency responses and lost sales (Villena and Gioia, 2020). The cost of this weaker disruption resilience is a direct hit to profitability when problems occur.

In summary, by forcing a firm into a transactional mode, complexity prevents the collaborative value creation that boosts profits. It simultaneously increases operational costs and risk related expenses. The financial statement impact is evident: lower potential revenue from missed innovation, higher selling, general and administrative expenses from constant monitoring, and unexpected costs from poor crisis management. Therefore, the opportunity cost imposed by complex, non collaborative supplier networks is a direct and significant constraint on a firm's profitability.

4.1.4. Theoretical Synthesis and Hypothesis

The three theoretical perspectives combine to form a clear and logical chain. They explain step by step how supply base complexity leads to lower profitability. This process is illustrated in the following conceptual map.

The conceptual map below shows the proposed sequence from cause to effect.

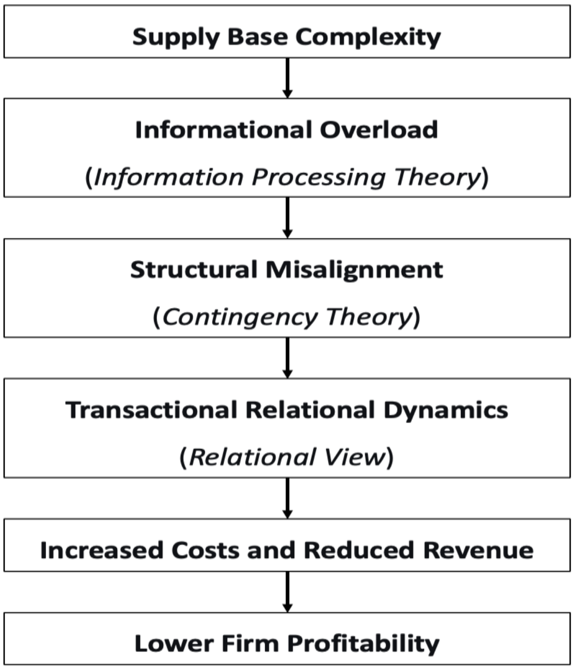

Figure 2: ***Conceptual Map***

Explanation of the logical sequence

First, a complex supply base creates an overwhelming amount of data and uncertainty. This is the problem of informational overload (Galbraith, 1974). A firm cannot effectively process all the information about its many suppliers and their interactions (Bozarth et al., 2009).

Second, this overload reveals a deeper organizational flaw. Most firms use structures designed for simpler environments. Their centralized and rigid designs are misaligned with the complex reality they face (Donaldson, 2001). This structural misfit, explained by Contingency Theory, turns information problems into operational failures like slow coordination and poor crisis response (Ates et al., 2020).

Third, struggling with these operational failures pushes firms into poor relationships with suppliers. To cope, they adopt simple, short term transactions instead of deep collaboration (Choi and Krause, 2006). This transactional approach, explained by the Relational View, forfeits the joint value creation, or relational rents, that comes from partnership (Dyer and Singh, 1998).

The final result of this chain is clear. The operational failures from misalignment and the lost value from poor relationships directly lead to higher operating costs and lower sales revenue. Together, these forces depress the firm's overall profitability.

This integrated framework provides strong theoretical support for a central claim about supply chain management. It leads directly to the following formal hypothesis:

H1: Supply base complexity is negatively associated with firm profitability.

4.2. Sustainability visibility moderates the relationship of complexity and profitability

While Hypothesis 1 establishes that supply base complexity harms profitability, this relationship is likely conditional. This section proposes that sustainability visibility can act as a moderator to weaken the negative effect of complexity on profit.

4.2.1. Theoretical Basis: How Visibility Counters the Core Problems

The moderating power of sustainability visibility is grounded in how its two pillars directly address the specific theoretical failure points that make complexity so costly. This interaction is visualized in the map below, which shows how the core capability of visibility intervenes in the negative cycle.

Theoretical Problem	Visibility Pillar	Counteracting Effect	Financial Outcome
1. Information Overload (IPT)	Information Accessibility	Enhanced Processing Capacity	Lower Cognitive C ost
2. Structural Misalignment (Contingency)	Adaptive Systems	Organizational Fit	Lower Coordination Cost
3. Transactional Relationships (Relational View)	Information Availability	Collaborative Governance	Lower Transaction Cost

Table 1: How visibility intervenes in the negative effect of complexity.

First, visibility tackles the fundamental problem of information processing overload. According to Information Processing Theory, organizational effectiveness depends on matching information processing capacity to environmental uncertainty (Galbraith, 1974). Complex supply bases generate overwhelming volumes of supplier data on performance, compliance, and interdependencies. When firms cannot process this data effectively, they make poor decisions about sourcing and inventory, resulting in what we term a "cognitive tax" on profitability (Bode and Wagner, 2015). The Accessibility pillar of sustainability visibility directly counters this problem. Integrated data platforms, standardized reporting systems, and analytical tools transform raw, fragmented data into structured, actionable intelligence (Gualandris et al., 2015). This increases the firm's effective information processing capacity, enabling better decisions about risk prioritization and resource allocation. For example, instead of holding excess inventory as a buffer against uncertainty, a firm with high visibility can make precise inventory decisions based on real time supplier performance data. This directly reduces costs and improves asset utilization.

Second, visibility enables the structural adaptation required to manage complexity effectively.Contingency Theory posits that organizational performance depends on achieving fit between internal structures and external environmental demands (Donaldson, 2001). Most firms retain centralized, rigid structures that are fundamentally misaligned with managing decentralized, dynamic supplier networks. This structural misfit creates coordination failures, slow crisis response, and inefficient oversight mechanisms that impose a "structural tax" on operations (Ates et al., 2020). Building visibility capabilities requires and enables adaptive structural changes. Implementing enterprise wide sustainability platforms necessitates cross functional coordination between procurement, sustainability, and operations teams. Establishing digital traceability systems often requires dedicated supplier relationship management roles and new governance committees (Busse et al., 2017). These changes create organizational structures that are inherently better aligned with managing complex networks. The firm develops what scholars term "ambidextrous" capabilities, balancing the need for centralized control with the flexibility required for local adaptation (Wiengarten et al., 2019). This structural realignment reduces the coordination costs and response delays that directly erode profit margins.

Third, visibility transforms the nature of buyer supplier relationships in ways that create economic value. The Relational View argues that competitive advantage stems not from individual firm resources but from valuable inter organizational relationships (Dyer and Singh, 1998). Complex supply bases typically push firms toward transactional, arms length relationships with suppliers to minimize coordination burden. These relationships forfeit what are called "relational rents" - the joint value created through collaboration, shared learning, and mutual investment. They also incur high transaction costs from continuous monitoring and renegotiation (Villena and Gioia, 2020). The Availability pillar of visibility, which depends on suppliers willingly sharing accurate, timely data, cannot be achieved through coercion alone. It requires developing trust based, collaborative partnerships. The process of co creating transparency, such as jointly developing data collection protocols or investing in shared traceability platforms, transforms the relational dynamic (Köhler and Pizzol, 2020). Suppliers transition from being monitored vendors to being accountability partners. This shift enables joint problem solving on sustainability challenges, co innovation in green products or processes, and shared risk management. These collaborative activities generate relational rents that directly enhance profitability while simultaneously reducing the costs of adversarial monitoring and enforcement.

In summary, sustainability visibility operates as a comprehensive organizational capability that simultaneously enhances information processing, enables structural adaptation, and transforms relational dynamics. It provides firms with the specific tools needed to convert the potential burden of supply base complexity into manageable, and even value creating, business processes.

4.2.2. The Moderating Mechanism

The strength of the negative relationship between supply base complexity and profitability depends critically on a firm's level of sustainability visibility. The moderating effect manifests through two distinct operational scenarios.

Scenario 1: Low Visibility with High Complexity
When a firm operates a complex supply network but has low sustainability visibility, it is effectively "blind" to the network's internal dynamics. This blindness prevents the firm from anticipating environmental or social risks embedded in its supply tiers. For example, it cannot detect poor labor conditions at a sub supplier or monitor a supplier's true carbon footprint (Tachizawa and Wong, 2014). Consequently, risks materialize as unexpected events. These include sudden disruptions from regulatory non compliance,

reputational crises from exposed labor violations, and inefficient operations due to a lack of data for optimization (Hendricks and Singhal, 2005). The firm incurs high reactive costs, such as emergency air freight, crisis management, and lost sales. In this state, the firm suffers the full force of the theoretical failure mechanisms. The negative impact of complexity on profitability is strong and largely unavoidable (Bode and Wagner, 2015).

Scenario 2: High Visibility with High Complexity Conversely, when high complexity is paired with high sustainability visibility, the firm gains "insight and control." The capabilities derived from the Two Pillars Framework enable proactive management. First, the firm can identify and mitigate sustainability risks before they escalate. It might use traceability data to audit a high risk tier two supplier or employ analytics to model carbon emissions across the network (Gualandris et al., 2015). This prevents costly disruptions and fines. Second, with accessible and reliable data, the firm can make strategic sourcing decisions based on total cost of ownership. This includes environmental and social risk premiums, not just piece price (Pagell and Wu, 2009). This allows for intelligent complexity reduction, such as consolidating suppliers in high risk regions. Third, transparency fosters trust based coordination with key suppliers, reducing the need for expensive, duplicative audits and enabling joint problem solving (Villena and Gioia, 2020). In this scenario, complexity remains, but the firm is equipped to manage it effectively. The visibility capability significantly reduces, or attenuates, the profitability penalty that complexity would otherwise impose.

In statistical terms, this describes a classic moderating interaction. High sustainability visibility flattens the steep negative slope between complexity and profit, transforming an overwhelming liability into a manageable operational reality.

4.2.3. Theoretical Synthesis and Hypothesis

Based on the integrated theoretical framework and the moderating mechanism described above, the second hypothesis is formed. This hypothesis explicitly tests the conditional relationship where the effect of the independent variable, supply base complexity, on the dependent variable, firm profitability, depends on the level of a third variable, sustainability visibility.

The logic developed in the preceding sections culminates in the following testable prediction. The established negative effect of complexity on profit is not a fixed law but is contingent on a firm's capability to achieve transparency across its supplier network. Therefore, a specific statistical interaction is hypothesized as followed:

> **H2: The negative relationship between supply base complexity and firm profitability is moderated by sustainability visibility, such that the relationship is weaker, or less negative, when sustainability visibility is high.**

This hypothesis is grounded in the theoretical synthesis that visibility counters the failure mechanisms of information overload, structural misalignment, and transactional relationships (Gualandris et al., 2015; Ates et al., 2020; Villena and Gioia, 2020). Statistically, support for H2 would be demonstrated by a significant interaction term between measures of complexity and visibility in a regression model predicting profitability. A confirmed H2 would provide empirical evidence that sustainability visibility is a critical strategic capability that can protect a firm's financial performance from the inherent costs of managing a complex global supply base.

4.3. Conceptual Model and Framework

This research is guided by a conceptual framework that integrates the direct and moderating relationships between the core constructs, as illustrated in the model above.

The framework posits a fundamental direct relationship where supply base complexity diminishes firm profitability (H1). This path represents the cumulative cost of informational, structural, and relational inefficiencies inherent in managing a complex supplier network.

Critically, the model introduces sustainability visibility as a moderating variable that alters the strength of this direct relationship. Grounded in the Two-Pillars Framework, visibility is conceptualized as a higher-order organizational capability comprising Information Accessibility (the firm's internal capacity to process data) and Information Availability (the collaborative, trust-based sourcing of data from suppliers). This capability does not eliminate complexity but provides the firm with the insight and control needed to manage it effectively.

The moderating effect (H2) is visualized by the dashed arrow influencing the main path. The model predicts that high levels of sustainability visibility will attenuate the negative slope of the relationship between complexity and profitability. In practical terms, while all firms face a profitability penalty from complexity, those with superior visibility capabilities will experience a significantly reduced penalty, thereby protecting their financial performance.

This framework synthesizes Hypotheses 1 and 2 into a testable model, positioning sustainability visibility not as a secondary concern but as a central strategic lever for profitability management in complex global supply chains.

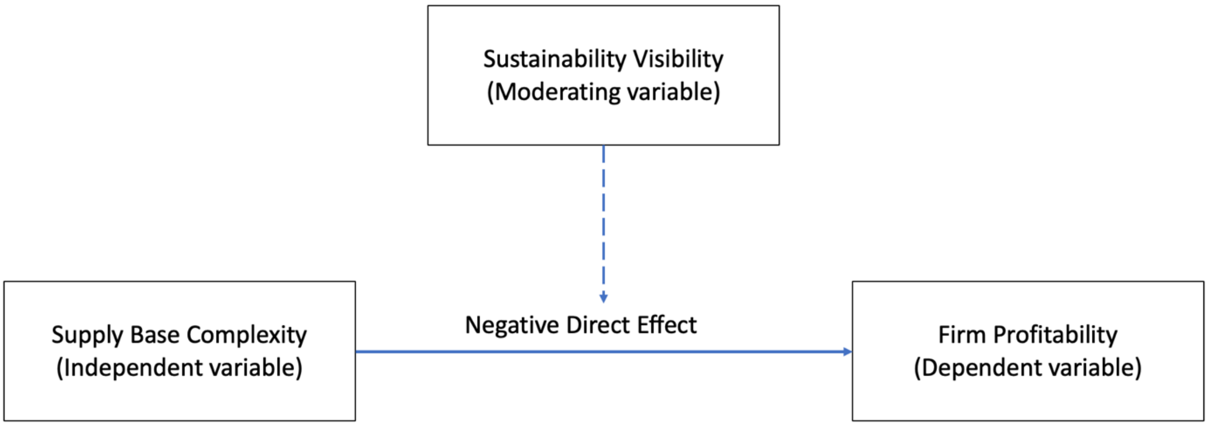

Figure 3: Conceptual Model

Chapter 3: Methodology

1. Data Collection and Sample

This research employs a quantitative, secondary data approach using firm-level information drawn from Refinitiv (LSEG) Workspace, one of the largest standardized databases for financial, ESG, and operational reporting. Refinitiv was selected due to its broad global coverage, consistent disclosure taxonomy, and availability of sustainability and governance-related indicators required to operationalize supply chain visibility constructs.

1.1. Sampling Frame

The initial sampling frame consisted of all companies included in the 2023 Fortune 100 ranking, representing some of the world's largest corporations spanning manufacturing, retail, consumer goods, logistics, technology, and service sectors. Fortune 100 firms provide a suitable context for this study for three reasons. First, they typically operate geographically dispersed supply networks across multiple tiers, making them inherently exposed to challenges related to supply base complexity. Second, these companies are known to act as early adopters of digital and analytics tools in supply chain management, which aligns with the study's focus on visibility-enabling technologies. Third, including both industrial and service-oriented companies allow for examination of cross-industry variation in digital transformation and visibility practices.

1.2. Time Period

Firm-level observations were collected for the 2021–2023 fiscal years. This period was deliberately selected because it captures the post-pandemic operational environment marked by supply chain shortages, rising ESG regulation, and accelerated investment in digital visibility solutions. Gathering data over three consecutive years supports panel-like variation and improves the robustness of statistical inference by allowing alignment of supply chain dynamics with performance outcomes.

1.3. Data Extraction and Screening

Data were collected from multiple Refinitiv modules, including financial disclosures, ESG reporting, digitalisation indicators, and governance metrics. Raw data were imported into Excel for screening, cleaning, and transformation. Companies with missing or incomplete values for individual indicators were retained in the dataset, with unavailable entries coded as null values. This approach preserves the breadth of the Fortune 100 sample while allowing statistical software to address missingness within the analysis phase rather than narrowing the sample scope

Although the Fortune 100 sample initially contained 100 firms, six companies were removed due to insufficient disclosure or unavailable visibility / supplier data across the three-year period. Thus, the final analytical dataset consists of 94 companies, yielding a total of 282 firm-year observations (94 firms × 3 years). The resulting sample remains diverse in industry representation, ensuring external validity and enabling comparison of differences in supply base complexity and digital visibility adoption between sectors.

2. Variable Operationalization and Measurement

All constructs in this study are operationalized using specific, standardized metrics available within the Refinitiv (LSEG) database. This approach ensures methodological rigor by providing consistency, objectivity, and replicability across the sample of Fortune 100 firms. The selection of each measure is grounded in established operations and finance literature, creating a direct, quantifiable link between the theoretical concepts of supply base complexity, sustainability visibility, and their hypothesized impact on financial performance.

2.1. Dependent Variable: Return on Assets (ROA)

Conceptual Definition: This refers to a company's success in generating earnings from its operations. It is the key outcome for assessing whether supply chain decisions lead to financial success.

Operational Measure and Construction:

Measured using Return on Assets (ROA), calculated as:

$$\text{ROA} = \frac{\text{Net Income}}{\text{Total Assets}}$$

Data for Net Income and Total Assets are taken directly from Refinitiv for each firm and year.

Justification: ROA is selected as the primary performance indicator because it serves as a robust, accounting-based measure of a firm's overall efficiency in generating earnings from its invested capital (Hendricks & Singhal, 2005). Unlike market-based measures influenced by investor sentiment, ROA directly reflects the outcomes of managerial decisions and operational execution. For this study, which investigates how strategic supply chain architecture (complexity) and management capabilities (visibility) impact operational efficiency, ROA provides an unambiguous and direct indicator of financial success. It answers the core research question of how effectively a firm's supply chain management contributes to the productivity of its entire asset base.

2.2. Independent Variable: Supply Base Complexity (Ln_Suppliers)

Conceptual Definition: Supply base complexity refers to the structural scale and relational breadth of a firm's upstream supplier network. It encapsulates the challenge of managing and coordinating across a large number of distinct supplier entities.

Operational Measure and Construction: This construct is operationalized as the natural logarithm of the annual count of a firm's active, high-confidence suppliers, denoted as Ln_Suppliers. The construction follows a meticulous, three-step process using Refinitiv's supply chain module to ensure the count reflects meaningful, ongoing relationships:

- **Temporal Activity Filter**: For a given fiscal year *t* (e.g., 2021), a supplier is classified as "active" if its record in the database has a last_update_date timestamp on or before December 31 of that year. This rule logically assumes a supplier relationship remains in effect from its last point of verification until new data indicates a termination or change.
- **Substantive Relationship Filter**: From this temporally active pool, only suppliers with a Refinitiv confidence_score of 30% or higher are retained. This proprietary score reflects the strength and verification level of the commercial link as determined by Refinitiv's methodology.
- **Statistical Transformation**: The raw annual count of qualifying suppliers was recorded. Observations with no relevant supplier data were explicitly coded as 0. The natural logarithm was then applied using the formula: Ln_Suppliers = ln(Supplier_Count + 1). The addition of 1 avoids mathematical undefined values for observations with zero suppliers.

Justification: This operationalization captures the core managerial challenge of overseeing numerous, substantive supplier relationships. Using the count of active, high-confidence suppliers ensures the measure reflects actual, ongoing business connections rather than unverified database entries. Explicitly coding missing data as zero provides a conservative and interpretable baseline, representing firms with no identifiable active supply chain in the database. The logarithmic transformation is standard practice to account for diminishing marginal effects, where adding a supplier to a small base has a greater relative impact than adding one to a large base. The resulting coefficient therefore indicates the percentage change in the dependent variable associated with a percentage change in supplier count, which is more interpretable for strategic decision-making (Bode & Wagner, 2015).

2.3. Moderator Variable: Sustainability Visibility (Sustainability_Visibility_Scores)

Conceptual Definition: Rooted in the Two-Pillars Framework, sustainability visibility is defined as a firm's institutionalized organizational capability to monitor, access, and process environmental and social (ESG) information across its multi-tier supply base. This invloves both the external mechanisms to obtain reliable data from suppliers (Information Availability) and the internal structures and processes to analyze, interpret, and act on that data (Information Accessibility).

Operational Measure and Construction: This capability is measured using a summative index named Sustainability_Visibility_Scores. The index aggregates a firm's disclosed implementation of 13 specific and verifiable supply chain sustainability management practices:

- **Data Source and Scoring**: The presence (1) or absence (0) of each practice is determined from standardized binary disclosure fields within Refinitiv's ESG and corporate responsibility modules. A score of 1 indicates the firm has implemented and publicly reported the practice for the fiscal year.
- **Index Calculation**: The annual Sustainability_Visibility_Scores is the arithmetic sum of these 13 binary indicators **(see Appendix 1)**, resulting in a discrete value ranging from 0 to 13. A higher aggregate score indicates a more comprehensive, mature, and institutionalized visibility capability.

Justification (Indicators Rationale): Each of the 13 indicators was selected for its direct contribution to the visibility construct:

- **Information Availability** (Indicators 1-11): These supplier-facing practices establish the external flow of information. They include foundational policies (Social Supply Chain Policy), communication and capacity-building (Supplier ESG Training, Supplier Environmental Policy Communication), systematic risk identification (Supplier Environmental Risk Assessment, Social Supply Risk Assessment), and governance mechanisms with consequences (Environmental Supply Chain Partnership Termination). Collectively, they represent the firm's structured effort to generate a reliable stream of sustainability data from its supply base.
- **Information Accessibility** (Indicators 12-13): These internal practices represent the firm's capacity to utilize the information obtained. Environmental Supply Chain Management signifies the existence of a dedicated internal function or management system, while Environmental Supply Chain Monitoring represents the ongoing activity of data verification and performance tracking. These two indicators capture the critical internal investments that transform raw supplier data into actionable managerial intelligence.

2.4. Control Variables

To isolate the hypothesized causal relationships and account for other determinants of firm profitability, firm size and temporal effects are included as statistical controls. All are sourced from Refinitiv's financial and company profile modules to maintain dataset consistency:

- **Firm Size (Ln_Assets):** Controlled using the natural logarithm of total assets. Firm size is a fundamental control, as larger organizations may benefit from economies of scale, possess greater market power, and have different risk profiles and resource allocations that independently influence profitability.
- **Temporal Effects (Year2022, Year2023):** Year Fixed Effects are incorporated through dummy variables for the 2022 and 2023 fiscal years, with 2021 serving as the reference category. This controls for macroeconomic shocks, industry-wide trends, regulatory changes, or systemic events (e.g., post-pandemic supply chain adjustments, inflationary periods) that equally affect all firms in the sample in a given year.

2.5. Interaction Term (Interaction_XM)

To empirically test the moderating hypothesis (H2), a multiplicative interaction term is created. This variable, labeled as Interaction_XM, is computed as the product of the standardized (z-scored) values of the independent variable (Ln_Suppliers) and the moderator variable (Sustainability_Visibility_Scores).

In the hierarchical regression analysis, a statistically significant coefficient for Interaction_XM would provide evidence supporting H2. It would indicate that the slope of the relationship between supply base complexity

(Ln_Suppliers) and firm profitability (ROA) is not constant but varies significantly depending on the level of sustainability visibility. Specifically, a positive and significant coefficient would suggest that higher visibility weakens the negative impact of complexity on profitability.

3. Data Analysis

The data analysis was conducted in two sequential phases using IBM SPSS Statistics. First, descriptive statistics and bivariate correlations were examined to understand the characteristics of the data and preliminary relationships among variables. Second, hierarchical multiple regression was employed to test the hypothesized relationships between supply base complexity, sustainability visibility, and firm profitability.

3.1. Descriptive Analysis

Prior to hypothesis testing, a descriptive analysis was performed to examine the central tendencies, variability, and distributions of all study variables. Means, standard deviations, minimums, and maximums were calculated for profitability (ROA), supply base complexity (lnSuppliers), sustainability visibility, and firm size (lnAssets). Visual inspections of distributions were conducted using histograms to assess normality and identify potential outliers. Bivariate relationships among variables were examined using Pearson correlation coefficients, with scatterplots generated to visualize linear associations. This preliminary analysis provided foundational insights into the data structure and informed subsequent regression modeling.

3.2. Hierarchical Regression Analysis

To test the study's hypotheses, a four-step hierarchical multiple regression analysis was conducted with profitability (ROA) as the dependent variable.

Variables were entered sequentially to assess their incremental explanatory power:

- Model 1 (Baseline): Included only control variables which are firm size (lnAssets) and year fixed effects (dummy variables for 2022 and 2023, with 2021 as reference).
- Model 2 (Direct effect of complexity): Added supply base complexity (lnSuppliers) to examine its direct relationship with profitability.
- Model 3 (Direct effect of visibility): Added sustainability visibility to test its unique contribution beyond complexity.
- Model 4 (Interaction model): Included the interaction term between supply base complexity and sustainability visibility (lnSuppliers × Visibility) to test for a moderating effect.

At each step, model fit was assessed using R^2, adjusted R^2, and the significance of R^2 change (ΔR^2). Hypothesis testing was based on the significance and direction of standardized regression coefficients (β) in the final model, with statistical significance set at *p* < .05 (two-tailed).

Chapter 4: Analysis and Result

1. Descriptive Analysis

1.1. Data Overview and Sample Characteristics

Descriptive statistics were computed for all study variables to examine their central tendencies, variability, distributions, and preliminary bivariate relationships. The analysis used data from 254 firms with complete observations across all variables (listwise N = 254). However, due to missing data in specific variables, the sample size for individual descriptive statistics varies, as detailed below.

1.2. Descriptive Statistics

Table 1 summarizes the descriptive statistics for the key variables. Supply base complexity, operationalized as the natural logarithm of the number of suppliers (lnSuppliers), was calculated using the formula lnSuppliers = ln(Supplier_Count + 1). This variable has N=264, indicating raw supplier count data was unavailable for 18 firm-year observations. For observations with data, this transformation handles zero counts appropriately while normalizing the distribution. The mean of 2.77 (SD = 1.34) corresponds to an average of approximately 16 suppliers after back-transformation, with raw counts varying widely across the sample.

Sustainability visibility, measured on a 0–13 scale based on monitoring and disclosure practices, had complete data for all 282 observations (M = 5.68, SD = 3.88). This wide standard deviation and full scale range indicate substantial variation in firms' adoption of visibility mechanisms.

Firm size, measured as the natural logarithm of total assets (lnAssets), also had complete data for 282 observations (M = 25.50, SD = 1.21), with an approximately normal distribution suitable for use as a control variable.

Profitability (ROA) was available for 272 observations (M = 6.68%, SD = 6.26%), ranging from -3.69% to 28.29%

VARIABLE	N	MINIMUM	MAXIMUM	M	SD
LNSUPPLIERS	264	0.00	5.37	2.77	1.34
SUSTAINABILITY VISIBILITY	282	0	13	5.68	3.88
LNASSETS	282	22.51	28.99	25.50	1.21
ROA (%)	272	-3.69	28.29	6.68	6.26

Note: *lnSuppliers = natural log of supplier count (Supplier_Count + 1); lnAssets = natural log of total assets.*

Table 2: Descriptive Statistics for Study Variables

1.3. Distribution Analysis

Visual inspection of histograms was conducted to assess the distributional properties of all study variables and to validate the statistical transformations applied. This step ensures that the assumptions underlying parametric regression analysis are reasonably met.

- **Supplier Count:** The distribution of the raw number of suppliers was highly right-skewed (see Figure 1). Most firms maintained fewer than 50 suppliers, while a small number managed several hundred, creating a long tail to the right. To correct for this severe non-normality, the transformation ln(Supplier_Count + 1) was applied. The resulting distribution of lnSuppliers (see Figure 2) is approximately normal, confirming the appropriateness of the transformation for subsequent analysis.

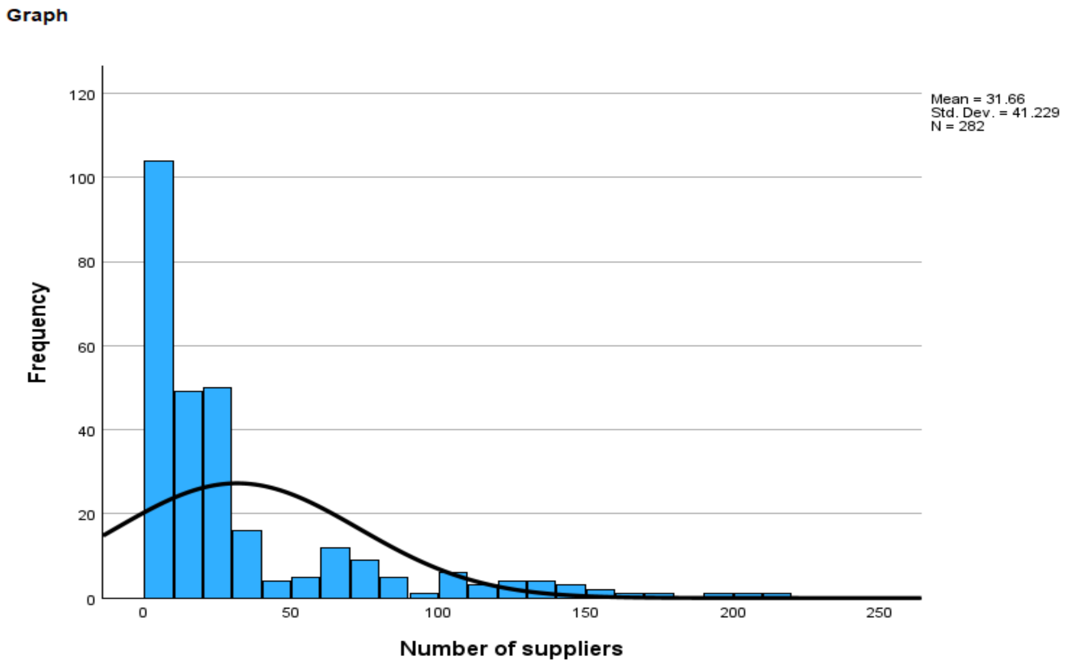

Figure 4: Histogram of Raw Supplier Count

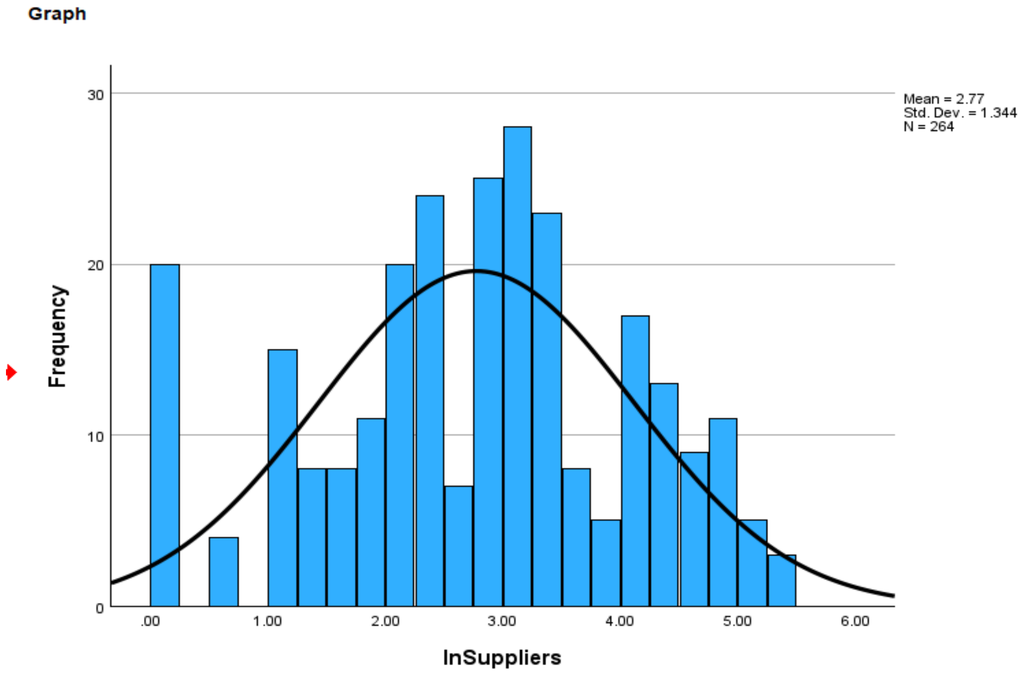

Figure 5: Histogram of lnSuppliers (ln(Supplier_Count + 1))

- **Firm Size**: A similar logarithmic transformation was applied to firm size, measured by total assets. The raw total assets data exhibited strong positive skewness. The transformation ln(Total_Assets + 1) was applied to produce lnAssets. The distribution of the transformed variable (see Figure 3) follows a near-normal distribution, validating its use as a control variable in the regression models.

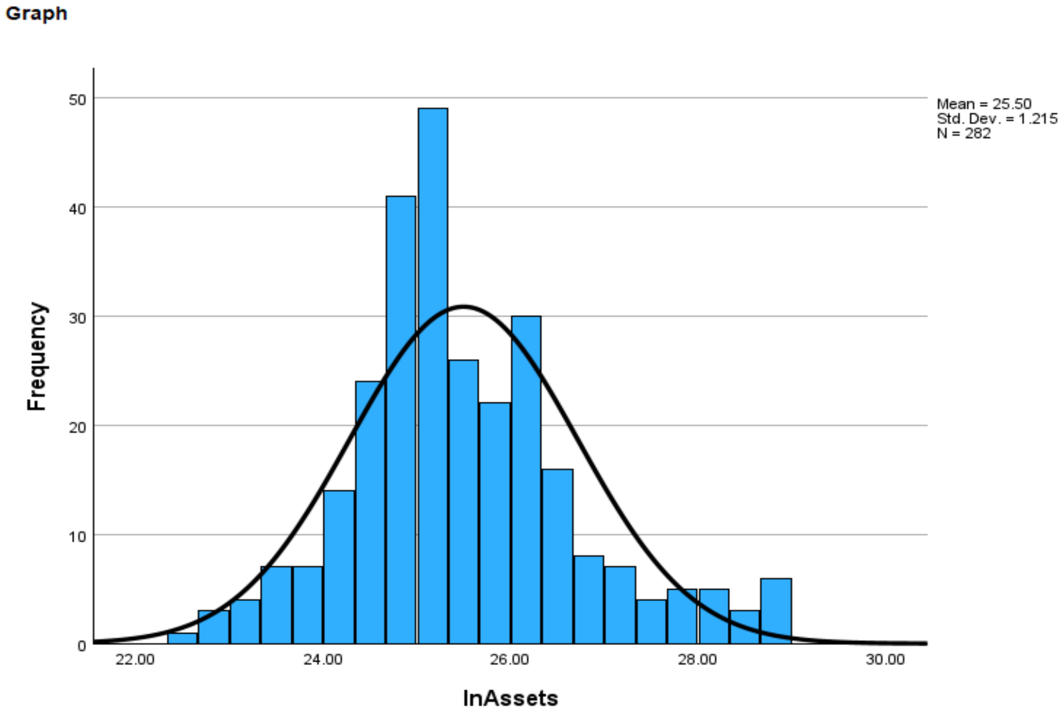

Figure 6: Histogram of lnAssets (ln(Total_Assets + 1))

- **Sustainability Visibility:** The distribution of sustainability visibility scores (see Figure 4) is fairly balanced across the 0–13 scale, with firms spread throughout the range without pronounced skewness. This indicates a diverse adoption of sustainability monitoring and disclosure practices within the sample.

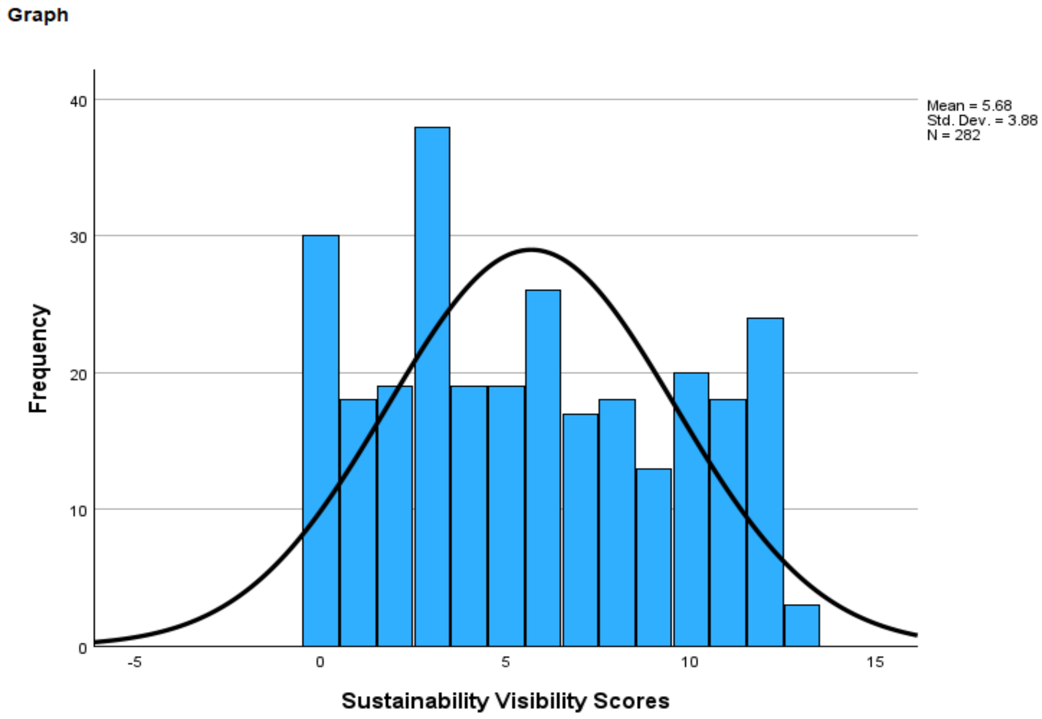

Figure 7: Histogram of Sustainability Visibility Scores

- **Profitability (ROA):** The distribution of return on assets (ROA) is moderately positively skewed (see Figure 5). The bulk of firms are clustered between 0% and 10% profitability, with a smaller group achieving returns above 20%, forming a tail toward higher performance.

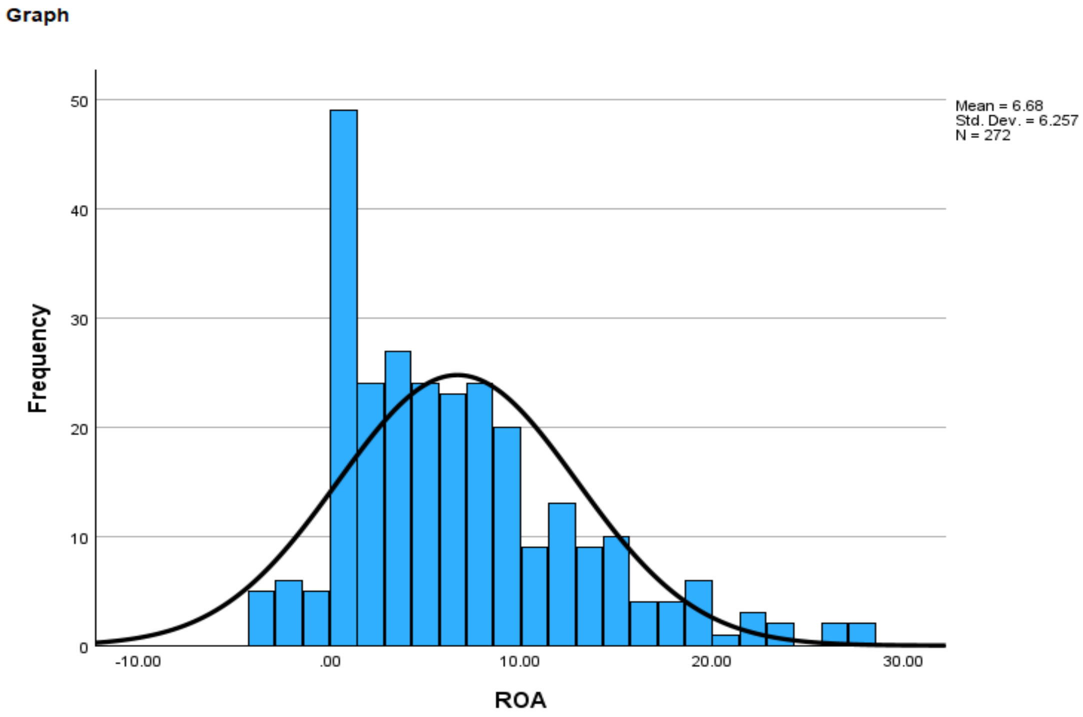

Figure 8: Histogram of ROA (%)

The examination of these distributions confirms that the key variables either naturally meet or have been transformed to reasonably meet the normality assumptions required for the planned hierarchical regression analysis.

1.4. Correlation Analysis

To examine the preliminary bivariate relationships between the study variables, Pearson correlation coefficients were calculated. The results, presented in Table 2, provide initial insights into the associations among supply base complexity, sustainability visibility, firm size, and profitability.

Several significant relationships were identified:

- **Profitability and Complexity**: Return on assets (ROA) shows a significant positive correlation with supply base complexity (*lnSuppliers*), with *r* = .157 (*p* = .012). This suggests that, at a bivariate level, firms with more extensive supplier networks tend to exhibit higher profitability.

- **Profitability and Visibility**: A stronger positive correlation exists between ROA and sustainability visibility, with *r* = .376 (*p* < .001). This indicates that firms with more comprehensive sustainability monitoring and disclosure systems are associated with significantly better financial performance.
- **Complexity and Visibility**: Supply base complexity and sustainability visibility are strongly positively correlated (*r* = .489, *p* < .001). This relationship suggests that firms managing larger, more complex supply bases are more likely to invest in enhanced visibility mechanisms, potentially as a response to greater operational and reputational risk exposure.
- **Firm Size and Profitability**: Firm size (*lnAssets*) is negatively correlated with ROA (*r* = -.172, *p*= .004), implying that larger firms, on average, may experience lower efficiency in generating profits from their assets compared to smaller firms.
- **Temporal Effects**: The year variable (*Year_num*) shows no significant correlation with ROA (*r* = .001, *p* = .989) or with the other primary variables, suggesting no strong temporal trend in profitability or the main constructs during the 2021–2023 sample period.

Variable	**1. ROA**	**2. lnAssets**	**3. lnSuppliers**	**4. Sustainability Visibility Score**	**5. Year_num**
1. ROA	1				
2. lnAssets	-.172** (.004)	1			
3. lnSuppliers	.157* (.012)	.287** (< .001)	1		
4. Sustainability Visibility Score	.376** (< .001)	.070 (.242)	.489** (< .001)	1	
5. Year_num	.001 (.989)	.017 (.775)	.021 (.735)	.104 (.080)	1

Note:

- **p* < .05, ***p* < .01 (two-tailed).*
- *Two-tailed *p*-values are shown in parentheses below each correlation coefficient.*
- *Sample sizes (pairwise N) are as follows: ROA correlations (N=254–272), lnAssets (N=264–282), lnSuppliers (N=264), Visibility (N=264–282)*

Table 3: **Pearson Correlation Matrix**

1.5. Preliminary Insights

The descriptive and correlational results provide important context for understanding the bivariate relationships among the key variables and highlight several patterns that will be examined more rigorously in the subsequent regression analysis.

First, the positive bivariate correlation between supply base complexity and profitability (*r* = .157, *p* = .012) presents an intriguing pattern that needs further investigation. While this initial association does not support the direction of H1 (which predicted a negative relationship), it underscores the need to examine this link within a multivariate framework that controls for other influential factors, such as firm size and sustainability visibility.

Second, the strong positive correlation between sustainability visibility and profitability (*r* = .376, *p* < .001) suggests that transparency and monitoring practices are closely associated with financial performance. This aligns with the theoretical expectation that visibility may enhance operational and reputational outcomes, a proposition that will be formally tested in the regression models.

Third, the strong positive correlation between complexity and visibility (*r* = .489, *p* < .001) indicates these constructs are closely interrelated. This relationship raises important questions about whether visibility mediates or moderates the complexity, which is central to H2.

Finally, the negative correlation between firm size and profitability (*r* = −.172, *p* = .004) confirms the importance of including firm size as a control variable, as it may confound the primary relationships of interest.

These preliminary insights do not constitute formal hypothesis tests but instead establish the empirical context and highlight the need for multivariate analysis. The following hierarchical regression will provide a more rigorous examination of H1 and H2 by controlling for relevant factors and testing for interaction effects.

2. Regression Analysis

2.1. Model Fit and Variance Explained

The regression results for model fit are summarized in Table 3. The baseline model with only control variables (Model 1) explained 3.5% of the variance in ROA ($R^2 = .035$). Adding supply base complexity (Model 2) significantly increased explained variance to 8.1% ($\Delta R^2 = .046$, *p* < .001). Introducing sustainability visibility (Model 3) produced the largest improvement, with R^2 rising to 18.5% ($\Delta R^2 = .105$, *p* < .001). Including the interaction term (Model 4) resulted in only a marginal increase to 19.0% ($\Delta R^2 = .005$, *p* = .225), which was not statistically significant. The final model explained 19% of the variance in profitability (Adj. $R^2 = .171$).

MODEL	R	R^2	ADJUSTED R^2	ΔR^2	F-CHANGE	SIG. F-CHANGE
1	.187	.035	.023	.035	3.010	.031
2	.284	.081	.066	.046	12.407	< .001
3	.431	.185	.169	.105	31.877	< .001
4	.436	.190	.171	.005	1.477	.225

Table 4: **Hierarchical Regression Model Summary**

2.2. Coefficient Estimates

The standardized (β) and unstandardized (B) coefficients for each predictor across the four models are presented in Table 4.

- **Firm size (lnAssets)**: Consistently showed a significant negative effect on profitability across all models (Model 4: $\beta = -.212$, *p* < .001).
- **Supply base complexity (lnSuppliers)**: Exhibited a significant positive association with profitability in Model 2 ($\beta = .223$, *p* < .001). However, this effect became non-significant when visibility was added in Model 3 ($\beta = .035$, *p* = .607), suggesting that the apparent benefit of complexity is explained by its correlation with visibility.

- **Sustainability visibility**: Emerged as a strong positive predictor of profitability in both Model 3 (β = .365, *p* < .001) and Model 4 (β = .368, *p* < .001).
- **Interaction term (lnSuppliers × Visibility)**: Was not statistically significant (β = -.070, *p* = .225), indicating no moderating effect.

Model	***Predictor***	***Unstandardized B***	***SE***	***Standardized β***	***t***	***Sig.***
1	Constant	28.864	8.205	—	3.518	<.001
	lnAssets	-0.881	0.320	-.171	-2.756	.006
	Year2022	0.966	0.984	.073	0.982	.327
	Year2023	0.071	0.978	.005	0.073	.942
2	Constant	37.185	8.365	—	4.445	<.001
	lnAssets	-1.205	0.326	-.234	-3.699	<.001
	Year2022	0.908	0.962	.068	0.944	.346
	Year2023	0.004	0.957	.000	0.004	.996
	lnSuppliers (Z)	1.414	0.401	.223	3.522	<.001
3	Constant	34.669	7.902	—	4.387	<.001
	lnAssets	-1.088	0.308	-.212	-3.531	<.001
	Year2022	0.221	0.916	.017	0.242	.809
	Year2023	-0.599	0.909	-.044	-0.648	.517
	lnSuppliers (Z)	0.223	0.433	.035	0.515	.607
	Visibility (Z)	2.431	0.431	.375	5.646	<.001
4	Constant	34.992	7.899	—	4.430	<.001

lnAssets	-1.091	0.308	-.212	-3.543	<.001
Year2022	0.154	0.916	.012	0.168	.867
Year2023	-0.643	0.909	-.049	-0.708	.480
lnSuppliers (Z)	0.256	0.434	.040	0.590	.556
Visibility (Z)	2.385	0.432	.368	5.524	<.001
Interaction	-0.448	0.369	-.070	-1.215	.225

Note. *Z = Z-scored (standardized) variable. Interaction = lnSuppliers × Visibility*

Table 5: Regression Coefficients for Hierarchical Models

3. Hypothesis Testing Results

3.1. Supply Base Complexity and Profitability (H1)

Based on the analysis, H1 is rejected. Contrary to the hypothesized negative relationship, supply base complexity exhibited a significant positive bivariate association with profitability (*r* = .157, *p* = .012). When entered in Model 2 of the hierarchical regression, complexity maintained this positive relationship (β = .223, *p* < .001), explaining an additional 4.6% of variance in ROA beyond control variables. However, when sustainability visibility was added in Model 3, the effect of complexity diminished to nonsignificance (β = .035, *p* = .607). This pattern indicates that the apparent positive effect of complexity is not direct but rather mediated through its strong association with visibility. The data provide no evidence that supply base complexity, in isolation, negatively impacts profitability; instead, any observed relationship appears contingent on whether firms with complex supply networks implement visibility mechanisms.

3.2. Moderating Role of Sustainability Visibility (H2)

Based on the analysis, H2 is rejected. The regression analysis tested whether sustainability visibility moderates the relationship between supply base complexity and profitability. Model 4 introduced the interaction term between complexity and visibility, which was not statistically significant (β = -.070, *p* = .225). The interaction contributed only 0.5% incremental variance explanation (ΔR^2 = .005), which did not reach statistical significance. This finding indicates that visibility does not alter the strength or direction of the complexity–profitability relationship. The benefits of visibility appear consistent across different levels of supply base complexity rather than being conditional on it. The nonsignificant interaction suggests that visibility operates through mechanisms that are largely independent of a firm's level of supply base complexity.

3.3. Post Hoc Finding: Direct Effect of Sustainability Visibility

Although H2 predicted a moderating effect, the regression revealed a direct positive effect of sustainability visibility on profitability. Across Models 3 and 4, visibility emerged as the strongest predictor of ROA (β = .375 and .368 respectively, both *p* < .001), accounting for 10.5% of additional variance when introduced in Model 3. This substantial effect size suggests that sustainability visibility represents a valuable strategic capability that enhances financial performance irrespective of supply chain structure. The strength and consistency of this relationship across models, even after controlling for complexity and firm size, underscores the importance of monitoring, transparency, and disclosure practices in supply chain management.

3.4. Summary of Hypothesis Outcomes

In summary, neither hypothesized relationship received empirical support. Complexity does not directly harm profitability as initially theorized, nor does visibility moderate the complexity–performance relationship. Instead, the results point to an alternative explanatory framework where visibility emerges as a powerful direct predictor of profitability, while complexity's apparent effect operates indirectly through its correlation with visibility. This pattern suggests that visibility may function as a mediator rather than a moderator in the supply chain management–performance relationship, a possibility that warrants further investigation in future research.

Chapter 5: Discussion and Conclusion

1. Summary of Key Findings

This study aimed to examine the relationships between supply base complexity, sustainability visibility, and firm profitability, through an integrated theoretical lens that combined Information Processing Theory (Galbraith, 1974), Contingency Theory (Donaldson, 2001), and the Relational View (Dyer & Singh, 1998). Contrary to the predictions from this synthesized framework, the empirical analysis reveals a more intricate, contingent, and capability-dependent narrative. This finding aligns with an emerging stream of supply chain literature that frames complexity not as an inherent liability, but as a structural condition whose impact is shaped by an organization's strategic and operational responses (Ates et al., 2020; Dubey et al., 2021).

First, Hypothesis 1, proposing a negative relationship between supply base complexity and profitability, was rejected. The established literature offers two compelling but contradictory rationales for this relationship. The traditional view, supporting H1, argues that complexity imposes significant costs: it strains a firm's information processing capacity (Bozarth et al., 2009), creates coordination failures due to structural misalignment (Choi & Krause, 2006), and pushes firms toward inefficient transactional relationships with suppliers (Wagner & Bode, 2014). These inefficiencies are theorized to create higher operational expenses, slower response times, and greater disruption vulnerability, ultimately eroding profit margins (Hendricks & Singhal, 2005). However, the results, which show a positive correlation that disappears when visibility is controlled, align more closely with a resource-based and strategic view. This perspective suggests that a diverse and extensive supply base can be a source of competitive advantage (Barney, 1991). It enables geographic arbitrage for lower input costs (Koufteros et al., 2007), access to specialized capabilities and innovations (Takeishi, 2002), and enhanced operational resilience through diversification (Sheffi & Rice, 2005). The crucial insight from the findings is that these benefits are not automatic; they are contingent. As hypothesized by Information Processing Theory, the informational and coordination demands of a complex network can overwhelm a firm unless it develops complementary capabilities. Based on this analysis, sustainability visibility emerges as the critical organizational capability that enables firms to unlock and realize the strategic potential inherent in their complex supply network structures. Thus, complexity alone is not detrimental; the burden or benefit hinges on the firm's ability to "see" and manage its network effectively. This refines the work of Bode and Wagner (2015) by suggesting complexity's effect is not direct but is filtered through managerial systems like visibility.

Second, hypothesis 2, which proposed that sustainability visibility moderates (in other words, weakens) the negative effect of complexity on profitability, was also not supported. The hypothesized moderation was rooted in the logic that visibility provides the "informational lubricant" to manage complexity, reducing friction and enabling coordination (Gualandris et al., 2015). A significant interaction term would have indicated that visibility's value is highest for highly complex firms. Instead, a direct positive main effect of visibility on profitability is found, irrespective of complexity levels. This suggests visibility operates not as a contextual buffer but as a valuable strategic capability. This finding extends the Two-Pillars Framework of visibility (Busse et al., 2017), positioning it firmly within the realm of dynamic capabilities (Teece et al., 1997). The capability to gather, analyze, and act upon sustainability intelligence (the "availability" pillar) and to integrate this intelligence into decision-making (the "accessibility" pillar) appears to generate value through multiple pathways. It enhances risk anticipation and mitigation (Wiengarten et al., 2019), fosters collaborative, trust-based supplier relationships that reduce transaction costs (Villena & Gioia, 2020), improves operational efficiency through better data-driven planning, and strengthens brand reputation and stakeholder trust (Marshall et al., 2015). These benefits are universal for firms, regardless of their level of complexity, which explains the insignificant interaction effect. Seeing clearly is valuable in itself; its worth is not dependent on anything else.

A particularly foundational finding was the strong positive correlation between supply base complexity and sustainability visibility itself. It indicates that firms with larger, more intricate supplier networks perceive and respond to greater risk exposure and stakeholder pressure (Hartmann & Moeller, 2014). Managing numerous suppliers across diverse geographies and regulatory amplifies environmental, social, and governance (ESG) risks (Tachizawa & Wong, 2014). In response to this exposure, and perhaps as a prerequisite for capturing the strategic benefits of a global network, these firms proactively invest in the monitoring, auditing, and reporting systems that constitute sustainability visibility. This finding bridges the structural and dynamic dimensions of complexity (Serdarasan, 2013) by showing how a large supply base drives dynamic capability development (investing in visibility).

Taken together, the results point toward a new way of thinking about these relationships. Rather than complexity directly harming profit or visibility simply moderating that effect, a mediation model better fits the data:

1. Complexity encourages firms to invest in sustainability visibility.
2. Visibility, in turn, directly enhances profitability.
3. Thus, the apparent link between complexity and profit is largely explained by the visibility systems that complex firms build.

This suggests that sustainability visibility is not just a risk management tool but a strategic capability that allows firms to harness the potential benefits of complex supply networks while managing the risks.

2. Answers to research questions

Based on the preceding literature review and analysis, this section presents the synthesized answers to the study's research questions. It consolidates the theoretical and empirical evidence to provide clear, substantiated conclusions regarding the direct relationship between supply base complexity and firm profitability, and the pivotal moderating role of sustainability visibility in transforming that relationship.

2.1. Research Question 1: How does supply base complexity affect firm profitability?

The results show that supply base complexity does not influence profitability in a simple positive or negative way. Instead, its impact depends on how firms react to the challenges created by a large and diverse supplier network. The findings suggest that complexity by itself is not harmful, but it increases managerial demands and requires firms to build stronger internal capabilities in order to perform well. A central insight of the study is that complex supply networks create a practical need for firms to develop more systematic approaches for monitoring suppliers and managing sustainability-related information.

When a firm works with many suppliers that differ in size, location, and role, the level of information required to coordinate activities becomes much higher, and uncertainty in daily operations increases as well (Bode & Wagner, 2015). This situation does not automatically reduce profitability; however, it makes managing the supply base more demanding and exposes firms to a greater risk of disruptions or information gaps. The evidence shows that firms do not passively accept these challenges. Instead, they respond by investing in sustainability visibility. The strong positive relationship between supply base complexity and visibility capability development indicates that firms actively adapt to complex environments rather than being constrained by them.

Because of this adaptive behavior, the effect of supply base complexity on profitability is mainly indirect. Complexity acts as a stimulus that encourages firms to strengthen their visibility systems and information-processing capabilities. These capabilities, which involve both obtaining data from suppliers and making that data usable inside the organization , then become the channels through which financial outcomes are shaped. Firms that successfully build such capabilities are better able to detect potential risks earlier, coordinate activities across supplier tiers, maintain more reliable and trust-based relationships with suppliers, and improve operational efficiency. As a result, visibility capabilities play a key role in translating the challenges of complex supply networks into improved performance and, ultimately, stronger profitability (Villena & Gioia, 2020; Wiengarten et al., 2019).

2.2. Question 2: What is the role of sustainability visibility in the relationship between supply base complexity and firm profitability?

The findings indicate that sustainability visibility does not moderate the relationship between supply base complexity and profitability. In other words, visibility does not weaken or alter the effect that complexity has on financial performance. Instead of acting as a conditional factor, visibility appears to operate independently of complexity. This outcome challenges the original expectation that visibility would serve as a buffer that softens the negative consequences of a complex supplier network.

The absence of a moderation effect provides an important insight into how visibility functions within firms. Its benefits to profitability appear consistent regardless of whether supply chains are relatively simple or highly complex. This suggests that visibility should be understood as a general strategic capability rather than a context-specific mechanism that only becomes valuable under conditions of complexity. Theoretically, this shifts visibility away from being a contingency-based resource and positions it as a capability that enhances performance in a broad range of supply chain environments.

The pattern of relationships observed in the analysis also points toward an alternative interpretation: rather than moderating the link between complexity and performance, visibility may mediate it. Firms with more complex supply bases tend to invest more heavily in visibility mechanisms, and these investments then contribute positively to profitability. This interpretation aligns with the positive association between complexity and visibility, alongside the strong direct effect of visibility on performance. In this view, complexity creates pressure for monitoring and control, prompting firms to develop visibility capabilities, and it is through these capabilities that performance benefits are realized.

This finding has practical and theoretical implications. For theory, it suggests that visibility should be treated as a capability that converts structural challenges into value, rather than merely a protective tool against complexity. For practice, it implies that firms should invest in sustainability visibility not only to respond to supply chain challenges but also to build enduring strategic advantages. Instead of treating visibility as a defensive exercise, managers can approach it as a capability development investment with systematic performance returns.

3. Contributions to the Field

This research provides several contributions to supply chain management theory and practice.

3.1. Theoretical Contributions

The study offers a revised view of supply base complexity. While existing literature often presents complexity as a factor that reduces performance due to information overload and coordination challenges (Bode & Wagner, 2015), the findings suggest a more conditional relationship. Rather than directly harming profitability, complexity appears to stimulate organizational responses, particularly in the form of sustainability visibility capability development. This positions complexity as a structural driver of adaptation rather than a purely negative condition.

The research also strengthens the understanding of sustainability visibility. Instead of treating visibility as a reporting requirement, the findings show it operates as a strategic capability that supports financial performance. Its direct positive influence aligns with the Resource-Based View, suggesting visibility represents a valuable and potentially rare organizational capability. The study further illustrates how structural characteristics of supply chains can push firms to develop capabilities that enhance performance, contributing to dynamic capability theory.

3.2. Empirical and Methodological Contributions

Methodologically, the thesis advances how key constructs are measured. It provides a practical way to calculate supply base complexity and introduces a multi-item visibility index rooted in real corporate disclosures. Using data from Fortune 100 firms between 2021 and 2023 adds current empirical insight from global firms operating in a period marked by post-pandemic disruption. The analytical approach allows the effects of complexity and visibility to be evaluated separately and together, helping clarify how they relate to performance.

4. Managerial Implications

This study presents several actionable insights for practitioners. First, the demonstrated link between visibility and profitability offers a strong business justification for investing in monitoring systems, supplier data platforms, and sustainability capabilities. These investments should be framed as sources of competitive advantage rather than compliance costs.

Second, instead of focusing narrowly on reducing supply base size, firms should assess whether they possess the capabilities required to manage complex networks. For companies with global or multi-tier sourcing structures, visibility systems should be developed alongside or prior to network expansion.

Third, managers should focus on both sides of visibility capability: Information availability (by building transparent relationships with suppliers that encourage data sharing) and information accessibility (by improving internal analytics capacity and integrating systems that turn data into actionable insights).

Fourth, visibility information should guide sourcing decisions. Rather than evaluating suppliers solely on cost, firms should consider total value, including sustainability risks and performance. This supports more informed supplier selection and partnership development.

Finally, the link between visibility and performance offers useful material for executive reporting and stakeholder communication, supporting alignment between sustainability goals and business strategy.

5. Limitations and Future Research Directions

This study also has limitations that open opportunities for future research.

First, because the research focuses on Fortune 100 firms, findings may not apply to smaller companies or those in different contexts. Future studies could explore how firm size, industry characteristics, or ownership models affect these relationships.

Second, while the three-year dataset offers temporal insight, it does not fully establish causality. Long-term studies or quasi-experimental research examining firms before and after visibility initiatives would strengthen causal interpretations.

Third, measurement approaches can be refined. Future research could incorporate additional dimensions of complexity (such as supplier diversity or interdependence) and deeper aspects of visibility, such as system integration or audit depth.

Fourth, the results suggest visibility may mediate the relationship between complexity and performance. Future work should test this mechanism formally and explore how visibility translates structural pressures into performance benefits, for example, through innovation, resilience, reduced disruption, or improved trust.

Finally, broadening performance outcomes beyond profitability would provide a more holistic understanding of visibility's value. Examining its effects on environmental impact, social outcomes, operational stability, and learning capacity could deepen theoretical and practical insight.

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Appendix

Appendix 1: Indicators for calculating sustainability

1. Supplier Environmental Due Diligence
2. Supplier Environmental Commitment
3. Supplier Environmental Policy Communication
4. Supplier Environmental Policy Training
5. Supplier ESG Training
6. Social Supply Chain Policy
7. Policy on Local Sourcing
8. Environmental Supply Chain Management
9. Environmental Supply Chain Monitoring
10. Supplier Environmental Risk Assessment
11. Social Supply Risk Assessment
12. Reporting of Findings from Supplier Monitoring
13. Environmental Supply Chain Partnership Termination