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# Intelligent Manufacturing as a Driver of ESG Performance: A Multiple-Case Study of Chinese Manufacturing Firms

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**Abstract:** This study examines how intelligent manufacturing contributes to enterprise environmental, social, and governance (ESG) performance through a multiple-case study of four Chinese manufacturing firms: Haier Smart Home, Midea Group, Contemporary Amperex Technology Co., Limited (CATL), and Seres. Existing studies increasingly suggest that intelligent manufacturing improves corporate sustainability outcomes, yet the literature remains more developed in identifying whether such effects exist than in explaining how they are generated within firms. Building on a mechanism-oriented qualitative design, this paper investigates four pathways through which intelligent manufacturing may affect ESG performance: information transparency, green technological innovation, financing conditions, and synergistic governance. The findings show that intelligent manufacturing enhances ESG performance not only by improving operational efficiency, but also by strengthening disclosure credibility, embedding green innovation into production systems, improving firms' financial resilience and external assessability, and reinforcing cross-functional and supply-chain coordination. At the same time, the cases indicate that these benefits are conditional rather than automatic. Their realization depends on the depth of digital integration, managerial commitment, and the firm's ability to convert technological upgrading into sustained organizational change. The study contributes to the literature by providing process-based evidence on how intelligent manufacturing becomes part of a firm's broader sustainability capability in practice.

**Keywords:** intelligent manufacturing; ESG performance; case study; digital transformation; green innovation; corporate governance

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## 1. Introduction

The simultaneous advance of digital transformation and sustainability governance has reshaped the strategic environment of manufacturing firms. In this context, intelligent manufacturing is no longer understood merely as a narrow technical upgrade in production. Rather, it is increasingly viewed as a broader organizational transformation involving real-time data collection, platform-based coordination, intelligent equipment, predictive control, and digitally integrated decision-making across the manufacturing life cycle<sup>[1]</sup>. This broader interpretation is especially important because firms are now judged not only by productivity and profitability, but also by their environmental responsibility, social performance, and governance quality. ESG performance has therefore become an increasingly influential benchmark of long-term corporate

development, while intelligent manufacturing has emerged as a major pathway through which firms attempt to reconcile technological upgrading with sustainable value creation.

Recent research has begun to establish a connection between intelligent manufacturing and ESG performance. A part of research exploit the Intelligent Manufacturing Pilot Projects (IMPP) implemented in China as a quasi-natural experiment and find that firms participate in the IMPP have significant improvements in ESG performance<sup>[2,3]</sup>. Meanwhile, some research find that intelligent manufacturing, measured through annual-report text analysis, significantly improves ESG performance<sup>[4]</sup>. Together, these studies move the conversation beyond conventional outcomes such as productivity, innovation output, and firm value<sup>[5,6]</sup>, and toward the broader sustainability consequences of manufacturing transformation.

However, the current literature still faces two limitations. First, much of the evidence is stronger on the question of whether intelligent manufacturing improves ESG than on the question of how this effect is produced within firms. Second, existing measurement strategies do not fully resolve the problem of organizational heterogeneity. Policy-based designs identify participation in intelligent manufacturing initiatives more easily than the intensity of firm-level implementation, while text-based proxies may capture disclosure behavior more readily than substantive organizational transformation. This leaves a clear need for mechanism-oriented evidence showing how intelligent manufacturing is translated into concrete ESG gains in practice.

Accordingly, the paper asks a focused question: through what organizational mechanisms does intelligent manufacturing contribute to enterprise ESG performance? By answering this question, the study aims to strengthen the connection between research on technological upgrading and research on sustainability governance.

## 2. Literature Background and Analytical Focus

The literature on intelligent manufacturing has traditionally concentrated on operational and economic outcomes, including production efficiency, innovation capability, quality upgrading, and firm performance. By contrast, research on ESG performance has more often focused on governance structure, external regulation, ownership characteristics, financial conditions, and broad forms of digital transformation. The result is a relative disconnect between studies of production-side technological change and studies of enterprise sustainability.

Within the emerging literature, several mechanism lines can be distinguished. One line emphasizes transparency and disclosure quality, arguing that intelligent systems improve the timeliness, accuracy, and traceability of firm-level information<sup>[7]</sup>. A second line focuses on green innovation<sup>[8,9]</sup>, suggesting that digitalized production makes resource inefficiencies more visible and supports cleaner product and process redesign. A third line highlights financing and resource conditions<sup>[10]</sup>, arguing that intelligent manufacturing may improve cash-flow stability, investor confidence, and access to sustainable finance. A fourth line stresses coordination and governance integration<sup>[11]</sup>, especially across supply chains and cross-functional systems.

The analytical focus of this paper is therefore not to re-test the general proposition that intelligent manufacturing is beneficial, but to explain how these mechanisms become observable in firms. This is precisely where case evidence is useful: it allows the research to move beyond reduced-form results and to trace the organizational pathways through which ESG improvement actually materializes.

## 3. Research Design

This study adopts a multiple-case design based on analytical replication. Case selection followed a logic of theoretical sampling. The selected firms had to satisfy four conditions: they needed to show substantive intelligent-manufacturing transformation rather than superficial digital adoption; they needed to illuminate one of the core mechanisms identified in the quantitative analysis; they needed to offer relatively rich and traceable public evidence; and together they needed

to form a replication-based case set in which each case supported the broader proposition while also revealing a distinct pathway. On this basis, Haier Smart Home, Midea Group, CATL, and Seres were selected.

The data sources are publicly available and authoritative materials, including annual reports, ESG or sustainability reports, official corporate disclosures, policy documents, and credible media coverage. A structured content analysis approach is used to reconstruct how intelligent manufacturing practices reshape information systems, innovation routines, financial conditions, and governance coordination, and how these changes support environmental, social, and governance outcomes.

## **4. Findings**

### **4.1. Haier: Information Transparency as an ESG Mechanism**

Haier Smart Home provides especially clear evidence for the information-transparency mechanism. Built around the COSMOPlat industrial internet platform, Haier's transformation links production, quality control, energy consumption, and supply-chain operations into a digitally connected information environment. The analytical significance of this case lies in the fact that information transparency is generated during operation, not simply added later at the disclosure stage. In traditional manufacturing settings, data on production progress, equipment status, and resource use are often fragmented and delayed. In Haier's case, intelligent manufacturing makes such data more visible, timely, and traceable.

This transformation improves ESG performance in three ways. First, real-time monitoring and integrated systems strengthen the visibility and verifiability of operational and environmental information. Second, better information quality reduces asymmetry between internal units and between the firm and external stakeholders. Third, stronger informational foundations support governance discipline and more credible ESG disclosure. The Haier case therefore shows that information transparency should not be treated narrowly as a communication practice; it is also a production-side organizational outcome of intelligent manufacturing.

### **4.2. Midea: Green Technological Innovation Embedded in Production**

The Midea case demonstrates how intelligent manufacturing improves ESG performance by embedding green technological innovation into the production system. Midea's Intelligent Industry Strategy links smart energy management, intelligent logistics, green product design, and resource recycling. The key point is that green innovation here is not isolated from day-to-day manufacturing. Instead, it becomes part of a wider operational capability through which environmental goals are integrated into process optimization and product development.

In this setting, intelligent manufacturing does more than improve efficiency. It makes process inefficiencies and carbon-intensive activities more visible, supports the redesign of energy use and logistics, and facilitates the scaling of cleaner products and processes. As a result, green technological innovation becomes more implementable and more measurable. This is why the Midea case offers persuasive support for the claim that intelligent manufacturing can improve ESG through a green innovation pathway.

### **4.3. CATL: Financing Conditions and Sustainability Capacity**

CATL provides insight into the financing pathway. In capital-intensive sectors, ESG improvement depends not only on managerial intention, but also on whether firms can sustain the required investments. According to the dissertation, CATL's extensive deployment of highly automated and intelligent production lines improves production efficiency, operational stability, and quality consistency. These improvements reduce business risk, strengthen cash-flow stability, and improve the firm's financial condition. At the same time, intelligent manufacturing enhances market confidence and facilitates access to external financing, including green credit and green bonds.

Importantly, the CATL case also indicates that this mechanism is not entirely linear. Intelligent transformation itself is capital-intensive, technologically demanding, and often associated with substantial upfront expenditure, long payback

periods, and adjustment pressure. As a result, intelligent manufacturing may simultaneously relieve financing frictions in the long run while creating new capital demands in the short to medium term. This is why the financing pathway should be interpreted as a dynamic tension between capability enhancement and transformation cost rather than as a simple easing effect. Even so, the CATL case clearly shows that when intelligent manufacturing strengthens operational stability, cash-flow resilience, and external financing credibility, it can expand the firm's capacity to undertake sustained ESG investment and thereby support stronger long-term ESG performance.

#### **4.4. Seres: Synergistic Governance Through Digital Integration**

Seres offers a particularly revealing case of how intelligent manufacturing can strengthen ESG performance through synergistic governance. As a technology-driven new-energy vehicle enterprise, Seres has developed a digital carbon-management platform and embedded intelligent systems into smart-factory operations, photovoltaic energy utilization, and real-time monitoring of production and energy consumption. At the same time, it extends these practices beyond the firm boundary by coordinating with upstream and downstream partners to promote low-carbon development across the supply chain. This case is analytically important because, in sectors characterized by technological complexity, rapid product iteration, and rising sustainability requirements, ESG performance depends less on isolated firm-level action than on the firm's capacity to orchestrate coordination across multiple organizational units and external actors.

From a governance perspective, the significance of intelligent manufacturing in the Seres case lies in its integrative function. Digital systems do not merely improve operational visibility; they also connect previously fragmented domains of decision-making, including production control, environmental monitoring, energy management, and supplier interaction. In doing so, they reduce governance problems rooted in information asymmetry, delayed feedback, and disconnected functional responsibilities. This means that governance improvement is not simply the result of stronger top-down control, but of a more responsive and interconnected organizational architecture in which relevant actors can coordinate on the basis of shared data and synchronized processes.

The broader implication of the Seres case is that synergistic governance should be understood as a concrete organizational outcome of digital integration. Intelligent manufacturing enhances ESG performance here because it allows the firm to align operational execution with sustainability objectives across departmental and supply-chain boundaries. In this sense, the contribution of intelligent manufacturing is not confined to efficiency gains; it also lies in building a governance infrastructure through which environmental goals, production routines, and stakeholder coordination can be managed in a more consistent and system-wide manner.

## **5. Discussion**

Taken together, the four cases suggest that intelligent manufacturing should be understood as a multidimensional organizational transformation with sustainability implications. It does not influence ESG through a single direct effect. Instead, it reshapes the internal conditions under which ESG performance becomes possible. Haier reveals the informational foundation of ESG management, Midea the innovation foundation, CATL the financial foundation, and Seres the governance foundation. This pattern is fully consistent with the dissertation's mixed-methods logic, in which case studies are used to bridge theoretical reasoning, econometric evidence, and real-world corporate practice.

These findings also caution against technological determinism. Intelligent manufacturing does not automatically produce ESG gains once digital systems are installed. The benefits observed in the cases depend on the depth of integration between technology, organizational routines, managerial commitment, and governance arrangements. Data transparency matters only when it supports real monitoring and decision-making. Green innovation matters only when it is embedded in scalable production systems. Better financing conditions matter only when they are converted into sustainability investment. Governance coordination matters only when digital platforms are linked to actual collaboration and oversight. Intelligent manufacturing is therefore best understood as an enabling but conditional pathway to ESG improvement.

From a theoretical standpoint, the study helps connect research on technological upgrading with research on sustainability governance. From a managerial standpoint, it suggests that firms should not pursue intelligent manufacturing solely as a route to efficiency. To translate digital transformation into ESG gains, firms need to align intelligent systems with disclosure practices, green innovation routines, financing strategies, and governance structures.

## 6. Conclusion

This paper has examined how intelligent manufacturing contributes to enterprise ESG performance through a multiple-case study of four Chinese manufacturing firms. The findings show that intelligent manufacturing improves ESG not only by enhancing production efficiency, but also by strengthening information transparency, embedding green technological innovation, improving financing conditions, and reinforcing synergistic governance. These mechanisms indicate that intelligent manufacturing is better understood as a broader capability-building process than as a narrow technological intervention.

The study also shows that the ESG effects of intelligent manufacturing are conditional rather than automatic. Firms benefit when digital upgrading is translated into integrated information systems, innovation routines, financial resilience, and collaborative governance arrangements. For this reason, intelligent manufacturing should be viewed as an important organizational pathway through which manufacturing enterprises can enhance their long-term sustainability capability. Future research could extend this analysis by comparing firms across industries and institutional settings, or by combining case evidence with richer longitudinal process data.

## Disclosure statement

The author declares no conflict of interest.

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