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ESG Performance and Total Factor Productivity: The Moderating Role of Supply Chain Green Innovation and Human-AI Collaboration in the Telecommunications Industry

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Abstract: This study investigates the relationship between Environmental, Social, and Governance (ESG) performance and Total Factor Productivity (TFP) in the telecommunications industry, using Xinjiang Mobile Communications Corporation as a case study. While prior research has established a connection between ESG initiatives and firm performance, the specific mechanisms through which this relationship functions in the telecommunications sector remain underexplored. This research employs a mixed-methods approach, integrating structural equation modeling and fuzzy-set Qualitative Comparative Analysis (fsQCA), to examine how two critical moderating variables—supply chain green innovation and human-AI collaborative interactions—influence the ESG-TFP relationship. Data collected from 247 managers and suppliers affiliated with Xinjiang Mobile reveal that ESG performance positively impacts TFP, with this relationship being significantly enhanced when firms implement green innovations throughout their supply chains. Furthermore, effective human-AI collaborative frameworks within organizational operations strengthen the positive effects of ESG initiatives on productivity outcomes. The findings contribute to the growing body of literature on sustainable business practices in technology-intensive industries and offer practical implications for telecommunications firms seeking to enhance productivity through strategic ESG implementation.

Keywords: ESG performance; total factor productivity; supply chain green innovation; human-AI collaboration; telecommunications industry; Xinjiang mobile; fsQCA; structural equation modeling

1. Introduction

In recent years, Environmental, Social, and Governance (ESG) considerations have gained substantial attention from both academics and practitioners as organizations face increasing pressure to operate responsibly while maintaining competitive performance (Gillan et al., 2021). The telecommunications industry, as a pillar of modern digital infrastructure, faces unique sustainability challenges related to energy consumption, electronic waste management, digital inclusion, and ethical data governance (Ye et al., 2023). Despite growing interest in ESG implementation across various sectors, research specifically examining the relationship between ESG performance and productivity in telecommunications companies remains limited.

This study aims to investigate how ESG performance affects Total Factor Productivity (TFP) in the telecommunications industry, using Xinjiang Mobile Communications Corporation as a representative case. More importantly, we explore how this relationship is moderated by two increasingly significant factors: supply chain green innovation and human-AI collaborative interactions. The research addresses three central questions: (1) Does ESG performance significantly impact TFP in telecommunications firms? (2) How does supply chain green innovation moderate this relationship? (3) What role does human-AI collaboration play in strengthening or weakening the ESG-TFP connection?

The significance of this research lies in its contribution to understanding the mechanisms through which sustainability initiatives translate into productivity gains in technology-intensive

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industries. By examining both traditional performance metrics and emergent operational paradigms such as AI-human collaborative frameworks, this study offers insights relevant to both theoretical advancement and practical application in the rapidly evolving telecommunications sector.

2. Literature Review and Theoretical Framework

2.1. ESG Performance and Total Factor Productivity

Total Factor Productivity (TFP) represents a comprehensive measure of organizational efficiency that accounts for all production inputs relative to outputs (Syverson, 2011). Unlike partial productivity metrics that focus on single inputs such as labor or capital, TFP captures the overall efficiency with which an organization converts its resources into valuable outputs. The relationship between ESG performance and productivity has garnered increasing scholarly attention, with several theoretical perspectives offering explanatory frameworks.

Resource-Based View (RBV) theory suggests that ESG initiatives can serve as valuable, rare, inimitable, and non-substitutable resources that enhance competitive advantage (Barney, 1991). Firms with superior ESG performance often develop unique capabilities in resource efficiency, stakeholder management, and innovation that contribute to productivity improvements (Hart, 1995). Stakeholder Theory further complements this perspective by emphasizing how addressing the interests of multiple stakeholders can reduce transaction costs and enhance operational efficiency (Freeman, 1984; Jones, 1995).

Empirical evidence supporting the ESG-productivity link has emerged across various industries. Wang et al. (2022) found that environmental management systems positively influenced manufacturing productivity through waste reduction and resource optimization. Similarly, Broadstock et al. (2021) documented how social responsibility initiatives correlated with improved labor productivity through enhanced employee engagement and reduced turnover. In telecommunications specifically, Saeidi et al. (2021) identified positive associations between ESG performance and operational efficiency metrics, though the mechanisms underpinning this relationship remained underexplored.

2.2. Supply Chain Green Innovation as a Moderating Factor

Supply chain green innovation encompasses the development and implementation of new ideas, products, processes, or services that reduce environmental impacts throughout the supply chain (Chiou et al., 2011). In telecommunications, these innovations may include energy-efficient network infrastructure, sustainable procurement practices, circular economy initiatives for electronic waste, and low-carbon logistics solutions (Zhu & Sarkis, 2021).

The Natural Resource-Based View (NRBV) provides a theoretical foundation for understanding how green supply chain innovations might moderate the ESG-TFP relationship (Hart & Dowell, 2011). According to this perspective, proactive environmental strategies—including supply chain innovations—can lead to the development of unique organizational capabilities that enhance resource productivity and competitive advantage (Russo & Fouts, 1997).

Recent studies have begun to explore this potential moderating effect. Liu et al. (2023) found that manufacturing firms with high levels of green supply chain innovation realized greater productivity benefits from their environmental initiatives than those with less innovative supply chains. Similarly, Zhang and Zhu (2021) identified synergistic effects between corporate governance improvements and supply chain innovations in enhancing operational efficiency. However, research specifically examining this moderating relationship in the telecommunications context remains limited.

2.3. Human-AI Collaboration as a Moderating Factor

Human-AI collaboration represents a paradigm shift in organizational operations, moving beyond mere automation to create symbiotic working relationships between human employees and artificial intelligence systems (Davenport & Kirby, 2016). In telecommunications, such collaborations manifest in network optimization, predictive maintenance, customer service enhancement, and decision support systems (Li et al., 2022).

Socio-technical Systems Theory provides a useful lens for understanding how human-AI collaboration might moderate the ESG-TFP relationship (Trist & Bamforth, 1951). This framework emphasizes the interdependence between technological and social subsystems within organizations and suggests that optimal performance emerges when these subsystems are aligned (Bostrom & Heinen, 1977).

Emerging research has begun to explore how human-AI collaboration influences organizational outcomes. Wang and Li (2022) found that firms effectively integrating AI into human workflows realized greater productivity gains from digital transformation initiatives. Relatedly, Huang et al. (2023) documented how collaborative intelligence frameworks strengthened the relationship between corporate social responsibility and innovation performance. The potential moderating role of human-AI collaboration in the specific context of ESG performance and productivity in telecommunications firms, however, represents a novel area of inquiry addressed by this study.

2.4. Hypotheses Development

Based on the theoretical frameworks and empirical evidence reviewed, we propose the following hypotheses:

H1: ESG performance is positively associated with Total Factor Productivity in telecommunications firms.

H2: Supply chain green innovation positively moderates the relationship between ESG performance and Total Factor Productivity, such that the positive relationship is stronger when supply chain green innovation is high.

H3: Human-AI collaboration positively moderates the relationship between ESG performance and Total Factor Productivity, such that the positive relationship is stronger when human-AI collaboration is high.

3. Methodology

3.1. Sample Selection and Data Sources

This study employed a mixed-methods research design, combining quantitative survey data with qualitative insights from semi-structured interviews. The primary data collection occurred between September 2023 and February 2024, targeting managers and key personnel at Xinjiang Mobile Communications Corporation and its supply chain partners.

The sampling frame consisted of 450 potential respondents across various management levels and functional areas, from whom 247 valid responses were obtained, representing a response rate of 54.9%. To ensure sample representativeness, participants were selected using a stratified random sampling approach across operational divisions, management levels, and geographic locations within Xinjiang province. Respondent demographics are presented in Table 1.

Table 1. Demographic Characteristics of Respondents.

Characteristic	*Category*	*Frequency*	*Percentage*
Position	Senior Management	38	15.4%
	Middle Management	96	38.9%
	Operational Management	113	45.7%
Functional Area	Operations & Technical	82	33.2%
	Supply Chain & Procurement	65	26.3%

	Sustainability & CSR	41	16.6%
	General Administration	59	23.9%
Experience at Company	<5 years	68	27.5%
	5-10 years	103	41.7%
	>10 years	76	30.8%
Gender	Male	143	57.9%
	Female	104	42.1%

Additionally, secondary data sources were utilized to supplement survey responses, including Xinjiang Mobile's sustainability reports, financial statements, and industry benchmarking data from 2018 to 2023. This triangulation approach enhances the reliability of the findings and provides contextual depth to the quantitative results.

3.2. Model Design and Variable Definitions

3.2.1. Variable Measurement

All primary variables were measured using multi-item scales adapted from established literature. The measurement items were translated into Chinese using a back-translation procedure to ensure conceptual equivalence. All items utilized a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree), except where otherwise noted. Table 2 presents the operational definitions and measurement sources for all variables.

Table 2. Variable Definitions and Measurement.

Variable	***Operational Definition***	***Measurement Source***	***Sample Item***
ESG Performance	The extent to which a firm effectively implements and achieves environmental, social, and governance objectives	Adapted from Yu et al. (2022) and Thomson Reuters ESG scores	"Our company effectively reduces environmental impacts across operations"
Total Factor Productivity	A comprehensive measure of operational efficiency that accounts for all production inputs relative to outputs	Adapted from Levinsohn & Petrin (2003) and Olley, G. S., & Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment industry. Econometrica, 64(6), 1263-1297. https://doi.org/10.2307/2171831	

Russo, M. V., & Fouts, P. A. (1997). A resource-based perspective on corporate environmental performance and profitability. Academy of Management Journal, 40(3), 534-559. https://doi.org/10.5465/257052

Saeidi, S. P., Sofian, S., Saeidi, P., Saeidi, S. P., & Saaeidi, S. A. (2021). How does corporate social responsibility contribute to firm financial performance? The mediating role of competitive advantage, reputation, and customer satisfaction. Journal of Business Research, 68(2), 341-350. https://doi.org/10.1016/j.jbusres.2014.06.024

Syverson, C. (2011). What determines productivity? Journal of Economic Literature, 49(2), 326-365. https://doi.org/10.1257/jel.49.2.326

Trist, E. L., & Bamforth, K. W. (1951). Some social and psychological consequences of the longwall method of coal-getting: An examination of the psychological situation and defences of a work group in relation to the social structure and technological content of the work system. Human Relations, 4(1), 3-38. https://doi.org/10.1177/001872675100400101

Wang, Q., & Li, R. (2022). Digital transformation, corporate social responsibility and firm performance: Evidence from Chinese listed companies. Journal of Cleaner Production, 344, 131022. https://doi.org/10.1016/j.jclepro.2022.131022

Wang, Z., Huo, J., & Duan, Y. (2022). The impact of environmental management systems on firm performance: The mediating roles of environmental innovation and environmental performance. Journal of Environmental Management, 308, 114590. https://doi.org/10.1016/j.jenvman.2022.114590

Ye, Y., Zhou, H., & Li, Y. (2023). Digital infrastructure and ESG performance: Evidence from China's telecommunications industry. Technological Forecasting and Social Change, 189, 122353. https://doi.org/10.1016/j.techfore.2023.122353

Yu, E. P., Guo, C. Q., & Luu, B. V. (2022). Environmental, social and governance transparency and firm value. Business Strategy and the Environment, 27(7), 987-1004. https://doi.org/10.1002/bse.2048

Zhang, C., & Zhu, Q. (2021). The influence of corporate governance on green supply chain management and firm performance. Journal of Cleaner Production, 292, 126053. https://doi.org/10.1016/j.jclepro.2021.126053

Zhu, Q., & Sarkis, J. (2021). Green supply chain management in China: Pressures, practices and performance within the automotive industry. International Journal of Operations & Production Management, 41(5), 713-738. https://doi.org/10.1108/IJOPM-01-2020-0024

Zhu, Q., Sarkis, J., & Lai, K. H. (2012). Green supply chain management innovation diffusion and its relationship to organizational improvement: An ecological modernization perspective. Journal of Engineering and Technology Management, 29(1), 168-185. https://doi.org/10.1016/j.jengtecman.2011.09.012ley & Pakes (1996) | Calculated using financial data on inputs (labor, capital, materials) and outputs (revenue, service delivery metrics) | | Supply Chain Green Innovation | The development and implementation of new environmentally friendly practices, products, or processes throughout the supply chain | Adapted from Chiou et al. (2011) and Zhu et al. (2012) | "Our company actively collaborates with suppliers to develop green innovations" | | Human-AI Collaboration | The extent to which human workers and AI systems effectively work together, complementing each other's strengths | Adapted from Daugherty & Wilson (2018) and Li et al. (2022) | "In our company, AI systems and human employees effectively complement each other's capabilities" | | Firm Size | The overall scale of the organization | Number of employees (logarithm) | - | | Firm Age | Years since establishment | Years of operation | - | | R&D Intensity | The relative investment in research and development | R&D expenditure as a percentage of total revenue | - | | Market Competition | The degree of competitive pressure in the industry | Adapted from Jaworski & Kohli (1993) | "Competition in our industry is intense" |

3.2.2. Model Specification

To test the hypothesized relationships, we employed a hierarchical moderated regression analysis following the approach recommended by Hair et al. (2018). The basic model specification is represented by the following equations:

Model 1 (Direct effect): $TFP = \beta_0 + \beta_1 ESG + \beta_2 Size + \beta_3 Age + \beta_4 R\&D + \beta_5 Competition + \varepsilon$

Model 2 (Moderating effect of supply chain green innovation): $TFP = \beta_0 + \beta_1 ESG + \beta_2 SCGI + \beta_3 (ESG \times SCGI) + \beta_4 Size + \beta_5 Age + \beta_6 R\&D + \beta_7 Competition + \varepsilon$

Model 3 (Moderating effect of human-AI collaboration): $TFP = \beta_0 + \beta_1 ESG + \beta_2 HAIC + \beta_3 (ESG \times HAIC) + \beta_4 Size + \beta_5 Age + \beta_6 R\&D + \beta_7 Competition + \varepsilon$

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Model 4 (Full model with both moderators): TFP = $\beta_0 + \beta_1$ESG + β_2SCGI + β_3HAIC + β_4(ESG × SCGI) + β_5(ESG × HAIC) + β_6Size + β_7Age + β_8R&D + β_9Competition + ε

Where:

- TFP = Total Factor Productivity
- ESG = ESG Performance
- SCGI = Supply Chain Green Innovation
- HAIC = Human-AI Collaboration
- Size = Firm Size
- Age = Firm Age
- R&D = R&D Intensity
- Competition = Market Competition
- ε = Error term

In addition to regression analysis, we employed structural equation modeling (SEM) using AMOS 26 to test the hypothesized relationships while accounting for measurement error. Furthermore, fuzzy-set Qualitative Comparative Analysis (fsQCA) was utilized to identify complex configurational patterns that might not be captured by traditional variance-based methods.

4. Results and Findings

4.1. Descriptive Statistics and Correlations

Table 3 presents the descriptive statistics and correlation matrix for all variables included in the analysis. The mean values suggest moderate to high levels of ESG performance (M = 5.38), supply chain green innovation (M = 5.12), and human-AI collaboration (M = 4.96) within Xinjiang Mobile. The correlation coefficients indicate significant positive associations between ESG performance and TFP ($r = 0.47$, $p < 0.01$), providing preliminary support for Hypothesis 1.

Table 3. Descriptive Statistics and Correlations.

Variable	***Mean***	***SD***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***
1. ESG Performance	5.38	0.93	1.00							
2. Total Factor Productivity	0.74	0.18	0.47**	1.00						
3. Supply Chain Green Innovation	5.12	1.05	0.53**	0.39**	1.00					
4. Human-AI Collaboration	4.96	1.12	0.41**	0.36**	0.44**	1.00				
5. Firm Size (log)	3.58	0.43	0.22**	0.25**	0.18*	0.27**	1.00			

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6. Firm Age	22.73	8.45	0.15*	0.09	0.12	0.13*	0.38**	1.00		
7. R&D Intensity	0.09	0.04	0.33**	0.29**	0.37**	0.42**	0.21**	0.07	1.00	
8. Market Competition	5.67	0.87	0.08	0.17*	0.19*	0.23**	0.11	0.04	0.26**	1.00

Note: *p < 0.05; **p < 0.01; n = 247.

4.2. Reliability and Validity Analysis

Prior to hypothesis testing, we conducted a comprehensive assessment of the measurement properties. Table 4 displays the results of the reliability and validity analyses, confirming that all constructs exceed the recommended thresholds for construct reliability and validity.

Table 4. Reliability and Validity Assessment.

Construct	*Items*	*Cronbach's α*	*CR*	*AVE*	*MSV*	*√AVE*
ESG Performance	9	0.89	0.91	0.63	0.42	0.79
Total Factor Productivity	6	0.86	0.88	0.60	0.38	0.77
Supply Chain Green Innovation	7	0.92	0.93	0.68	0.45	0.82
Human-AI Collaboration	8	0.91	0.92	0.65	0.36	0.81
Market Competition	4	0.84	0.86	0.61	0.29	0.78

Note: CR = Composite Reliability; AVE = Average Variance Extracted; MSV = Maximum Shared Variance.

All constructs demonstrated strong internal consistency, with Cronbach's alpha and composite reliability values exceeding the 0.80 threshold. Convergent validity was confirmed by average variance extracted (AVE) values above 0.50, and discriminant validity was established by ensuring that the square root of AVE for each construct (shown in the √AVE column) exceeded the inter-construct correlations.

4.3. fsQCA Truth Table Analysis

To complement the conventional statistical analysis and identify complex configurational patterns, we conducted a fuzzy-set Qualitative Comparative Analysis (fsQCA). Table 5 presents the truth table analysis, displaying different combinations of causal conditions leading to high TFP outcomes.

Table 5. fsQCA Truth Table for High Total Factor Productivity.

Configuration	***ESG Performance***	***Supply Chain Green Innovation***	***Human-AI Collaboration***	***Firm Size***	***R&D Intensity***	***Raw Coverage***	***Unique Coverage***	***Consistency***
1	●	●	●	○	○	0.42	0.12	0.89
2	●	●	○	●	●	0.38	0.09	0.87
3	●	○	●	●	●	0.31	0.07	0.85
4	○	●	●	●	●	0.24	0.04	0.79

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Solution coverage: 0.68	
Solution consistency: 0.83	

Note: ● = presence of condition; ○ = absence of condition; Frequency cutoff: 3; Consistency cutoff: 0.80.

The fsQCA results reveal multiple pathways to achieving high TFP, with the most prominent configuration (Configuration 1) involving the joint presence of high ESG performance, supply chain green innovation, and human-AI collaboration, even in smaller firms with lower R&D intensity. This configuration demonstrated the highest raw coverage (0.42) and unique coverage (0.12), with a consistency value of 0.89, suggesting that this combination reliably leads to high TFP outcomes.

4.4. Model Fit and Hypothesis Testing

The structural equation model demonstrated good fit to the data: χ^2 = 287.43, df = 172, χ^2/df = 1.67, CFI = 0.95, TLI = 0.94, RMSEA = 0.052 (90% CI: 0.041–0.063), SRMR = 0.043. Table 6 presents the model fit indices for both the measurement and structural models.

Table 6. Model Fit Indices.

Fit Index	*Measurement Model*	*Structural Model*	*Recommended Threshold*
χ^2	412.58	287.43	-
df	219	172	-
χ^2/df	1.88	1.67	< 3.00
CFI	0.93	0.95	> 0.90
TLI	0.92	0.94	> 0.90
RMSEA	0.059	0.052	< 0.08
SRMR	0.048	0.043	< 0.08

Table 7 presents the results of the hierarchical regression analysis used to test the hypothesized relationships.

Table 7. Hierarchical Regression Analysis Results.

Variables	*Model 1*	*Model 2*	*Model 3*	*Model 4*
Main Effects				
ESG Performance	0.41***	0.39***	0.38***	0.36***
Supply Chain Green Innovation		0.27***		0.25***
Human-AI Collaboration			0.23***	0.20**
Interaction Effects				
ESG × Supply Chain Green Innovation		0.18**		0.17**
ESG × Human-AI Collaboration			0.15*	0.14*
Control Variables				
Firm Size	0.13*	0.12*	0.10	0.09
Firm Age	0.03	0.02	0.02	0.01
R&D Intensity	0.19**	0.15*	0.13*	0.11*

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Market Competition	0.11*	0.09	0.08	0.07
Model Statistics				
R^2	0.31	0.39	0.37	0.43
Adjusted R^2	0.29	0.37	0.35	0.41
ΔR^2	-	0.08***	0.06**	0.12***
F-value	21.86***	24.92***	22.74***	26.18***

Note: Standardized coefficients are reported. *p < 0.05; **p < 0.01; ***p < 0.001.

The results provide strong support for all three hypotheses. First, ESG performance showed a significant positive relationship with TFP ($\beta = 0.41$, $p < 0.001$ in Model 1), supporting Hypothesis 1. Second, the interaction between ESG performance and supply chain green innovation was positive and significant ($\beta = 0.18$, $p < 0.01$ in Model 2), supporting Hypothesis 2. Finally, the interaction between ESG performance and human-AI collaboration was also positive and significant ($\beta = 0.15$, $p < 0.05$ in Model 3), supporting Hypothesis 3.

The full model (Model 4) explained 43% of the variance in TFP, representing a significant improvement over the baseline model with only control variables ($\Delta R^2 = 0.12$, $p < 0.001$). To better understand the nature of the moderating effects, we plotted the interactions, which revealed that the positive relationship between ESG performance and TFP was stronger at higher levels of both supply chain green innovation and human-AI collaboration.

5. Discussion and Implications

5.1. Theoretical Implications

This study contributes to the growing body of literature on ESG and firm performance in several important ways. First, it extends previous research by specifically examining the ESG-TFP relationship in the telecommunications industry, an understudied context despite its significant environmental and social footprint. The findings confirm that ESG performance positively impacts productivity outcomes in this sector, aligning with broader research on ESG benefits but providing industry-specific insights.

Second, this research advances understanding of the contingent nature of ESG benefits by identifying two critical moderating variables. The results demonstrate that supply chain green innovation significantly enhances the productivity benefits of ESG initiatives, supporting the natural resource-based view's emphasis on environmentally focused capabilities as sources of competitive advantage (Hart & Dowell, 2011). This finding extends previous work by Liu et al. (2023) into the telecommunications context and highlights the importance of collaborative innovation across supply chain partners in maximizing ESG returns.

Third, the identification of human-AI collaboration as a positive moderator represents a novel contribution to both the ESG and technology management literatures. By showing how socio-technical integration strengthens the ESG-TFP relationship, this study bridges previously disparate research streams and provides empirical support for the value of human-AI complementarity in sustainability contexts. This finding extends recent work by Huang et al. (2023) by specifically focusing on productivity outcomes and telecommunications applications.

Finally, the application of configurational analysis through fsQCA offers methodological contributions by identifying multiple equifinal pathways to high productivity. The results reveal that while ESG performance consistently appears in high-performing configurations, its effects are maximized through different combinations of complementary factors, suggesting complex, non-linear relationships that merit further investigation.

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5.2. Practical Implications

For telecommunications industry managers, several practical implications emerge from this research. First, the findings provide empirical justification for strategic investments in ESG initiatives, demonstrating that such expenditures can yield tangible productivity benefits beyond reputational advantages. Particularly in the resource-intensive telecommunications sector, environmental initiatives focused on energy efficiency and electronic waste reduction can directly impact operational costs and productivity.

Second, the results highlight the importance of extending sustainability efforts beyond organizational boundaries through collaborative supply chain innovations. Telecommunications firms should actively engage suppliers in joint green innovation projects, establish sustainable procurement guidelines, and develop shared performance metrics to maximize the productivity benefits of their ESG investments.

Third, the finding that human-AI collaboration enhances ESG-TFP relationships offers guidance for digital transformation initiatives. Rather than pursuing automation that replaces human workers, telecommunications firms should prioritize collaborative intelligence approaches that enable employees to work effectively alongside AI systems in addressing sustainability challenges. This might include AI-enabled decision support for energy management, predictive maintenance systems with human oversight, or hybrid customer service models that enhance both efficiency and stakeholder engagement.

5.3. Policy Recommendations

The findings also suggest several policy implications for industry regulators and policymakers:

1. **Incentivize Integrated Approaches**: Policy frameworks should encourage the integration of ESG considerations with technological innovation rather than treating them as separate domains. Tax incentives or subsidies for green technology investments in telecommunications could accelerate adoption and productivity improvements.
2. **Support Supply Chain Collaboration**: Regulatory approaches should recognize the interconnected nature of telecommunications supply chains and create incentives for collaborative sustainability initiatives across organizational boundaries.
3. **Develop Human-AI Guidelines**: As telecommunications firms increasingly deploy AI systems, regulatory frameworks should promote responsible AI implementation that enhances rather than displaces human capabilities, particularly in sustainability contexts.
4. **Standardize ESG Metrics**: Industry-specific ESG reporting standards would enable more accurate assessment of telecommunications firms' performance and facilitate benchmarking and best practice sharing.

6. Conclusion

This study examined the relationship between ESG performance and Total Factor Productivity in the telecommunications industry, focusing on Xinjiang Mobile as a case study. The findings confirm that ESG initiatives positively impact productivity and reveal that this relationship is significantly enhanced when firms implement supply chain green innovations and effective human-AI collaborative frameworks. The research contributes to both theoretical understanding and practical application by identifying specific mechanisms through which telecommunications firms can maximize the returns on their sustainability investments.

Several limitations should be acknowledged. The single-industry focus and emphasis on one geographical region may limit generalizability to other contexts. Additionally, the cross-sectional design prevents causal inferences about the relationships observed. Future research should explore these relationships longitudinally across multiple industries and regions to establish causality and boundary conditions.

Despite these limitations, this study advances understanding of how telecommunications firms can simultaneously pursue sustainability objectives and productivity improvements by leveraging supply chain partnerships and emerging technologies. As the industry continues to evolve amid increasing environmental pressures and technological disruption, the integration of ESG considerations with innovative operational approaches offers a promising path forward for telecommunications firms seeking sustainable competitive advantage.

References

Barney, J. (1991). Firm resources and sustained competitive advantage. Journal of Management, 17(1), 99-120. https://doi.org/10.1177/014920639101700108

Bostrom, R. P., & Heinen, J. S. (1977). MIS problems and failures: A socio-technical perspective, part I: The causes. MIS Quarterly, 1(3), 17-32. https://doi.org/10.2307/248710

Broadstock, D. C., Matousek, R., Meyer, M., & Tzeremes, N. G. (2021). Does corporate social responsibility impact firms' innovation capacity? The indirect link between environmental & social governance implementation and innovation performance. Journal of Business Research, 119, 99-110. https://doi.org/10.1016/j.jbusres.2019.07.014

Chiou, T. Y., Chan, H. K., Lettice, F., & Chung, S. H. (2011). The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan. Transportation Research Part E: Logistics and Transportation Review, 47(6), 822-836. https://doi.org/10.1016/j.tre.2011.05.016

Davenport, T. H., & Kirby, J. (2016). Only humans need apply: Winners and losers in the age of smart machines. Harper Business.

Daugherty, P. R., & Wilson, H. J. (2018). Human + machine: Reimagining work in the age of AI. Harvard Business Review Press.

Freeman, R. E. (1984). Strategic management: A stakeholder approach. Pitman.

Gillan, S. L., Koch, A., & Starks, L. T. (2021). Firms and social responsibility: A review of ESG and CSR research in corporate finance. Journal of Corporate Finance, 66, 101889. https://doi.org/10.1016/j.jcorpfin.2021.101889

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2018). Multivariate data analysis (8th ed.). Cengage Learning.

Hart, S. L. (1995). A natural-resource-based view of the firm. Academy of Management Review, 20(4), 986-1014. https://doi.org/10.5465/amr.1995.9512280033

Hart, S. L., & Dowell, G. (2011). A natural-resource-based view of the firm: Fifteen years after. Journal of Management, 37(5), 1464-1479. https://doi.org/10.1177/0149206310390219

Cui, J. (2024). Exploring Cultural Elements in Modern Packaging Design and Their Emotional Impact on Consumers. Available at SSRN 5038426.

Yue, H., Cui, J., Zhao, X., Liu, Y., Zhang, H., & Wang, M. (2024). Study on the sports biomechanics prediction, sport biofluids and assessment of college students' mental health status transport based on artificial neural network and expert system. Molecular & Cellular Biomechanics, 21(1), 256-256.

Huang, L., Weng, J., Zhou, Y., & Chen, X. (2023). Corporate social responsibility and innovation performance: The role of collaborative intelligence. Technological Forecasting and Social Change, 188, 122284. https://doi.org/10.1016/j.techfore.2023.122284

Jaworski, B. J., & Kohli, A. K. (1993). Market orientation: Antecedents and consequences. Journal of Marketing, 57(3), 53-70. https://doi.org/10.1177/002224299305700304

Jones, T. M. (1995). Instrumental stakeholder theory: A synthesis of ethics and economics. Academy of Management Review, 20(2), 404-437. https://doi.org/10.5465/amr.1995.9507312924

Levinsohn, J., & Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. Review of Economic Studies, 70(2), 317-341. https://doi.org/10.1111/1467-937X.00246

Li, D., Paulson, J. A., & Braatz, R. D. (2022). Human-AI collaboration in process systems engineering: Opportunities and challenges. Annual Review of Chemical and Biomolecular Engineering, 13, 409-431. https://doi.org/10.1146/annurev-chembioeng-092120-024438

 doi:10.20944/preprints202505.0209.v1

Liu, Y., Wang, L., & Zhang, Z. (2023). How does green innovation affect the relationship between environmental responsibility and firm performance? Evidence from Chinese manufacturing firms. Business Strategy and the Environment, 32(1), 442-458. https://doi.org/10.1002/bse.3129