Nanostore Supply Chain Performance: Meta-Analysis of Industry 4.0 and 5.0 Integration for Human-Centric and Sustainable Retail

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Abstract*– This meta-analysis of 52 recent studies evaluates the impact of Industry 4.0 and 5.0 technologies on nanostore supply chains, using a methodology adapted from established frameworks. The analysis revealed a moderate to large effect size (Cohen's d = 0.8) for improved supply chain performance, emphasizing the value of digitalization combined with human-centric and sustainable approaches. Industry 4.0 technologies, including IoT and AI, enhance operational efficiency, inventory management, and customer satisfaction, while Industry 5.0 principles improve resilience and adaptability. Notably, Industry 5.0 supports customer-centric, sustainable models without compromising efficiency. Emerging technologies, such as advanced robotics for inventory automation and digital twins for real-time supply chain monitoring, show promise for further enhancing nanostore logistics. However, methodological variability and a focus on Latin America and the Middle East limit generalizability. Standardizing methodologies and expanding geographical scope could strengthen future research. Nanostores benefit from these technologies, and policy support through funding and training can accelerate adoption. This study advances the discourse on digital transformation in informal retail, offering actionable insights for nanostore competitiveness and sustainable development.

Keywords--Nanostore Supply Chain Performance, Human-centric design, Sustainability, inventory management, logistics coordination, and customer satisfaction.

I. Introduction

A. Background and Justification of the Study

The global retail landscape is undergoing a significant transformation with the advent of Industry 4.0 and Industry 5.0, two technological revolutions that are redefining supply chain operations and customer interactions. Industry 4.0, characterized by automation, the Internet of Things (IoT), and data exchange in manufacturing and supply chains, has already demonstrated its impact on retail operations [1]. Meanwhile, Industry 5.0 builds upon this foundation, shifting the focus toward human-centric design, sustainability, and hyper-personalization, thereby opening new possibilities for small-scale retailers, such as nanostores [2].

Nanostores, small-scale retailers prevalent in emerging economies, play a vital role in local economies by acting as last-mile distributors and fostering economic inclusivity [3]. Their efficiency and adaptability are crucial in sustaining the flow of goods and ensuring market penetration in underserved regions [4]. However, despite their significant role in local economies, nanostores face distinct operational and technological challenges, which hinder their ability to fully leverage the advancements brought about by Industry 4.0 and 5.0. Yet, research on integrating Industry 4.0 and 5.0 technologies into the supply chains of nanostores remains limited, particularly in emerging markets [5].

Given the growing importance of digital transformation in retail, it is vital to understand how technological advancements affect nanostores. Unlike larger firms, these stores face constraints such as limited digital infrastructure, financial restrictions, and informal management, which hinder technology adoption and weaken competitiveness. Therefore, examining the barriers and enablers of adoption, as well as reviewing Industry 4.0 and 5.0 literature to identify existing gaps, is essential [6-8].

B. Literature Review and Research Gaps

Numerous studies have explored the influence of Industry 4.0 on large-scale manufacturing and supply chain operations, emphasizing automation, data analytics, and artificial intelligence [5]. However, much of the current research focuses on large enterprises, which often benefit from economies of scale and robust infrastructure—conditions that differ starkly from those of nanostores [8]. Similarly, while Industry 5.0 introduces a paradigm shift toward human-centric technology adoption and sustainable business models, its practical implementation in small-scale retail supply chains remains an underdeveloped research area [9].

The first gap in the literature is the limited empirical evidence on how Industry 4.0 and 5.0 technologies influence operational performance, logistics, and supply chain efficiency in nanostores. Although some studies have highlighted the potential of these technologies for improving supply chain efficiency in larger organizations, little is known about their specific impacts within the resource-constrained environments of nanostores [6-8], leaving a gap in understanding how digitalization, automation, and AI-driven decision-making can be leveraged within the constraints of nanostores [9]. Addressing this gap may unlock new strategies for improving their sustainability, resilience, and competitiveness in an increasingly digital economy [10].

The second gap concerns the insufficient exploration of the practical implications of integrating these advanced technologies within small retail environments [11-13]. Most research fails to address how the unique characteristics of nanostores—such as their resource constraints, limited digital literacy, fragmented supply chains, and informal management structures interact with these emerging technologies [14]. This results in a poor understanding of how these contextual limitations affect the feasibility and scalability of technological solutions.

These gaps highlight the need to explore how Industry 4.0 and 5.0 technologies can be tailored and scaled to improve the operational and strategic performance of nanostores, reinforcing their role in modern supply chains. This study responds by formulating research questions and objectives to guide the investigation.

C. Research Questions and Objectives

The aim of this study is to bridge these gaps by synthesizing the available evidence on the impact of Industry 4.0 and 5.0 technologies on the supply chains of nanostores. Specifically, this research seeks to address the following research questions:

How have Industry 4.0 and 5.0 technologies been integrated into the supply chains of nanostores, and what evidence exists regarding their impact on supply chain performance?

2) What are the key challenges and opportunities associated with the adoption of these technologies in small-scale retail enterprises?

3) How can Industry 5.0 principles, such as sustainability and human-centric design, be effectively implemented in nanostores to enhance supply chain resilience?

To address these research questions, the objectives of this study have been formulated to provide a comprehensive analysis of the integration and impact of Industry 4.0 and 5.0 technologies within nanostore supply chains. By examining the extent to which these technologies have been adopted and their effects on operational performance, logistics, and resilience, this study aims to offer a detailed understanding of the potential benefits and challenges. The study also explores strategic applications of Industry 5.0 principles to boost competitiveness through sustainable, human-driven models.

The objectives of this study are as follows:

1) To evaluate the extent to which Industry 4.0 and 5.0 technologies have been integrated into the supply chains of nanostores, focusing on their performance and logistics.

2) To identify the primary challenges and opportunities facing nanostores in adopting these technologies and propose strategies for overcoming these challenges.

3) To assess the potential of Industry 5.0 to revolutionize nanostore supply chains by fostering human-centric design and enhancing sustainability.

These research questions and objectives guide the study's analysis of Industry 4.0 and 5.0 in nanostore supply chains, ensuring a systematic exploration of their influence on logistics, operational efficiency, resilience, and adaptability.

This paper is structured as follows: Section II reviews Industry 4.0 and 5.0 technologies in nanostore supply chains, covering key frameworks and findings. Section III details the meta-analysis methodology, including data collection and literature scope. Section IV presents the meta-analysis results, exploring technological adoption trends and implications for nanostores. Section V summarizes findings, discusses limitations, and suggests future research directions, providing insights for academics and industry stakeholders.

II. Literature Review, State of the Art, and Conceptual Framework

A. Literature Review

The integration of Industry 4.0 technologies within supply chains has gained significant attention in recent decades. Studies have demonstrated the transformative potential of automation, artificial intelligence (AI), and the Internet of Things (IoT) in enhancing the efficiency and adaptability of supply chains in large enterprises, particularly in manufacturing, logistics, and distribution sectors. Early works in this area focused on industrial applications and large-scale manufacturing, with limited attention to their applicability in small retail environments like nanostores [15].

While the impact of Industry 4.0 on large-scale enterprises has been widely studied, its implications for small-scale retail—especially nanostores—remain underexplored. This research seeks to bridge this gap by investigating how these technologies can be adapted to suit the operational realities of nanostores [16-18].

More recent studies have begun to explore how small-scale retail operations, particularly in emerging economies, can benefit from Industry 4.0 technologies [19]. However, significant barriers still exist to effective implementation, especially when considering their impact on supply chain efficiency and long-term sustainability. This lack of a comprehensive framework highlights the need for further research focused on small-scale, resource-constrained retail operations [7].

In addition, while Industry 5.0 is a new concept, it has generated growing interest due to its emphasis on human-centric design, collaboration between humans and machines, and a focus on sustainability [20]. Although early research on Industry 5.0 has primarily concentrated on large enterprises and manufacturing contexts, its application to small-scale retail operations, such as nanostores, remains underexplored. There is limited scholarly exploration of how these human-centric principles might be operationalized in the unique context of nanostores [21].

B. State of the Art

Recent advancements in Industry 4.0 and Industry 5.0 technologies are shaping the future of supply chain management, particularly within small and medium-sized enterprises (SMEs) [22]. The application of AI, blockchain

technology, and data-driven analytics in supply chains has significantly improved operational performance, logistics coordination, and customer service across various industries [23]. However, while these technologies have proven effective in larger businesses, their uptake among nanostores is still in the early stages. Empirical studies evaluating their concrete impacts on nanostore supply chains are scarce.

Current studies suggest that nanostores have the potential to benefit from these technologies by improving inventory management, customer engagement, and supply chain resilience [24]. However, literature highlights several challenges, including limited digital infrastructure and financial constraints, which make the adoption of advanced technologies in nanostores difficult. Discussions in the literature are increasingly addressing both contextual barriers and adaptive strategies for implementing these solutions in resource-constrained settings [5]. Despite these discussions, there is still limited empirical evidence on how Industry 4.0 and Industry 5.0 technologies are currently being adopted in nanostore supply chains, and what barriers exist for their implementation [8].

Industry 5.0 adds complexity by emphasizing sustainability, ethics, and the integration of human and technological intelligence. This human-centric approach could reshape nanostore operations by enhancing collaboration between workers and technology. However, research still lacks integrative models to assess its transformative impact in micro-retail contexts [25].

C. Conceptual Framework and Propositions

Building on gaps in the literature, this study proposes a conceptual framework that integrates Industry 4.0 and 5.0 technologies into nanostore supply chains, tailored to challenges such as limited resources, space constraints, and informal management.

The theoretical underpinning of this framework is based on the premise that the adoption of Industry 4.0 technologies—such as IoT, AI, and data analytics—can enhance the operational efficiency and resilience of nanostore supply chains [26]. This framework integrates elements of digital transformation, aiming to empower nanostores with tools that improve both efficiency and customer-centric operations. Furthermore, the integration of Industry 5.0 principles—such as sustainability, human-centric design, and ethical considerations—can foster more resilient and adaptable supply chain networks in small-scale retail environments [5].

This study advances theory by examining the integration of Industry 4.0 and 5.0 in nanostore ecosystems. Unlike large enterprises, where their transformative potential is well documented, applying these technologies in small-scale retail presents distinct challenges and opportunities [6].

Building on these findings, the proposed conceptual framework aims to bridge this limitation by examining the role of both Industry 4.0 and Industry 5.0 in enhancing nanostore supply chain performance. In this study, nanostore supply chain performance is conceptualized in two key dimensions. The first dimension focuses on operational efficiency, which includes inventory management, logistics coordination, and customer satisfaction. The second dimension addresses resilience and adaptability, which reflect the ability of nanostores to respond effectively to disruptions and evolving market conditions [27].

Inventory management in nanostores involves optimizing stock levels, minimizing shortages, and reducing waste. This is achieved through smart technologies like AI-driven demand forecasting and IoT-based real-time tracking. Logistics coordination involves the efficient movement of goods, ensuring timely restocking and improved last-mile delivery services through digital integration. Customer satisfaction is defined as the extent to which nanostores meet consumer expectations by offering product availability, fast service, and personalized shopping experiences enabled by digital tools [28].

Resilience is the capability of nanostores to withstand and recover from supply chain disruptions, such as demand fluctuations or logistical bottlenecks, by leveraging adaptive and technological strategies. Adaptability refers to the agility of nanostores in adjusting to changes in market conditions, consumer preferences, and technological advancements, ensuring long-term competitiveness and sustainability [29].

The following propositions are derived from the challenges identified in literature and the theoretical underpinnings of this framework.

1) Proposition 1: The adoption of Industry 4.0 technologies in nanostore supply chains will significantly enhance nanostore supply chain performance, particularly in inventory management, logistics coordination, and customer satisfaction.

2)Proposition 2: The integration of Industry 5.0 principles—particularly sustainability and human-centric design—will improve nanostore supply chain performance, particularly in resilience and adaptability.

These propositions lay the groundwork for the empirical analysis presented in subsequent sections of this paper, advancing research on the practical applications of Industry 4.0 and Industry 5.0 in small-scale retail environments, and contributing to a deeper understanding of their potential impacts.

III. Research Methodology and Data Collection

A. Research Design

This study uses a meta-analysis, based on [30], to synthesize research on Industry 4.0 and 5.0 technology integration in nanostore supply chains. It evaluates studies to identify patterns, trends, and gaps [31], aggregating quantitative and qualitative evidence for robust effect estimates. Addressing fragmented research on small-scale retail, it systematically assesses technological transformation using both quantitative and qualitative meta-analytic techniques, with selective qualitative synthesis (e.g., thematic coding) to enhance understanding where quantitative data is limited.

B. Data Sources and Search Strategy

A structured search was conducted across key academic databases—Scopus, Web of Science (WoS), EBSCOhost, and JSTOR—focusing on peer-reviewed journal articles, conference papers, and books published between 2000 and 2024. To enhance coverage, supplementary searches were performed using Google Scholar and institutional repositories, targeting working papers and preprints that offer emerging insights into Industry 4.0 and 5.0 applications in retail.

Search Strategy:

1) Automated and manual searches were performed to ensure comprehensive coverage, minimizing the risk of selection bias.

2) Keywords: A combination of terms in English and Spanish was used, including Industry 4.0, Industry 5.0, nanostores, supply chain integration, retail logistics, artificial intelligence, IoT, and sustainability in small-scale retail.

3*) Boolean Operators:* These were employed to refine the search results and target studies pertinent to the topic.

C. Inclusion and Exclusion Criteria

To ensure the relevance and quality of the studies included in the meta-analysis, the following criteria were applied:

1) Publication Type: Only peer-reviewed journal articles, books, and conference papers were included.

2) Document Sources: Studies were sourced from Scopus, WoS, JSTOR, and EBSCOhost.

3) Time Frame: Publications from 2000 to the present were considered, with a focus on the last two decades to capture the latest advancements.

4) Geographical Focus: Special emphasis was placed on studies relevant to emerging markets, particularly in Latin America and the Middle East, to align with the context of nanostores. These regions are critical due to rising digitalization needs and the prevalence of informal retail. To ensure a well-rounded perspective, studies from developed economies were also included when they offered transferable insights into small-scale retail adaptation of Industry 4.0 and 5.0 technologies.

D. Variables and Data Collection

The meta-analysis focused on several key variables to assess the impact of Industry 4.0 and 5.0 technologies on nanostore supply chain performance (e.g., inventory management, logistics coordination) and business outcomes (e.g., customer satisfaction, operational resilience).

1) Adoption of Technologies: IoT, AI, blockchain.

2) Principles of Industry 5.0: sustainability and human-centric design.

3) Nanostore Supply Chain Performance Metrics: Inventory management, logistics coordination.

4) Business Outcomes: Customer satisfaction, operational resilience.

Data was extracted and coded from the results sections of the included studies, following a standardized process to ensure consistency and reliability. A dual-coding approach was implemented, where two independent reviewers analysed and categorized the data to mitigate subjective biases and enhance coding reliability.

E. Data Analysis and Validation

The data was analysed using meta-analytic techniques to synthesize results across studies:

1) Effect Size Calculation: The effect sizes were computed for each study, and a random-effects model was used to aggregate these sizes due to the expected variability between studies.

2) Heterogeneity Analysis: The presence of heterogeneity was assessed using Cochran's Q test and I^2 statistics, indicating the extent of variability due to factors other than sampling error.

3) Sensitivity Analysis: This involved excluding specific studies to test the robustness of the overall findings and ensure that results were not overly influenced by individual studies.

4) Publication Bias Assessment: Funnel plots and Egger's test were used to identify potential publication bias by examining the symmetry of the funnel plot and performing statistical tests for asymmetry.

5) Proposition Testing: To evaluate Proposition 1, the data on operational performance (inventory management, logistics coordination, customer satisfaction) will be synthesized from studies that examine the effect of Industry 4.0 technologies. Similarly, Proposition 2 will be evaluated by synthesizing data from studies that evaluate the impact of Industry 5.0 principles on resilience and adaptability.

6) To further strengthen the validity of findings, cross-validation was conducted by comparing results across different analytical models, including fixed-effects and Bayesian meta-analysis techniques, ensuring that conclusions remain stable across methodological variations.

F. Moderator and Subgroup Analysis

To explore how different study characteristics might influence the effect sizes, moderator and subgroup analyses were conducted. This included examining:

1) Study Quality: Comparing results from high-quality versus lower-quality studies.

2) Population Characteristics: Variations based on demographic or regional factors.

3) Intervention Characteristics: Differences in the type, dosage, or implementation of Industry 4.0 and 5.0 technologies.

4) Contextual Factors: Including geographical and cultural influences on study outcomes. A specific focus was placed on examining institutional readiness and the availability of digital infrastructure, as these factors may significantly influence the success of Industry 4.0 and 5.0 implementations in nanostores. For instance, poor infrastructure could delay or distort the expected performance outcomes of IoT and AI integration.

Moderator and Proposition Testing: This section also examined how these moderators influence the testing of the propositions. Geographical and institutional contrasts were mapped to assess their moderating influence on adoption–performance relationships.

G. Cumulative Meta-Analysis

A cumulative meta-analysis was performed to observe how the effect sizes evolved as additional studies were included over time. This analysis helps in understanding trends and shifts in the research field and provides insights into how the evidence base has developed [5],[31]. This process identified inflection points marked by significant post-pandemic growth in technological adoption among small-scale retailers.

H. Graphical Representation

1) Trend Analysis Plot: A graphical representation of technology adoption trends over time highlighted inflection points in Industry 4.0 and 5.0 integration within nanostore supply chains.

2) Forest Plot was used to visually represent the effect sizes from individual studies and the overall combined effect. It included confidence intervals to show the precision of the estimates.

3) *Funnel Plot* was employed to assess publication bias and ensure that the meta-analysis results were not skewed by the selective publication of studies. Supplementary visualizations (e.g., bubble plots) were used where needed to illustrate moderator effects.

I. Ethical Considerations

While this meta-analysis does not involve direct human participants, ethical considerations were addressed through:

1) Transparency: Ensuring all data used was publicly available and properly cited to uphold academic integrity.

2) Respect for Intellectual Property: Proper citation of all sources to acknowledge the original authors' contributions.

3) Ethical Implications of Findings: Considering the potential social and environmental impacts of promoting Industry 5.0 technologies in small-scale retail environments. This includes labor displacement, digital exclusion, and equity in technological access. Future efforts should emphasize actionable mitigation strategies such as reskilling, inclusive design, and public-private support mechanisms.

IV. Analysis, Results, and Discussion

A. Analysis of Meta-Analytic Data

1) Effect Size Calculation and Summary: This meta-analysis included 52 studies assessing the impact of Industry 4.0 and 5.0 technologies on nanostore supply chain performance. A random-effects model was used due to study variability. The pooled effect size was Cohen's d = 0.8 (95% CI: [0.50, 0.80]), indicating a moderate to large positive impact.

The inclusion of studies from various geographies, business models, and technological contexts enhances the generalizability of findings. This aligns with previous research on the role of Industry 4.0 and 5.0 technologies in SMEs, particularly in retail [32-36].

These results coincide with recent studies, such as those by [37] and. [35], who also identified moderate to high positive impacts from the use of advanced technologies in the supply chains of small retail businesses. However, this study stands out by applying a quantitative meta-analysis approach in the context of nanostores, a population scarcely addressed. Thus, the analysis not only validates previous findings but also broadens their scope by standardizing results, responding to the need for comparability highlighted by authors such as Escamilla and Fransoo [11] in their critical review of studies on digitalization in microenterprises.

Table I summarizes the effect sizes across the included studies, including important variables such as group sample size, mean values, and standard deviations. This table provides an overview of the study characteristics and their contribution to the overall effect size calculation.

TABLE I
SUMMARY OF EFFECT SIZES FROM INCLUDED STUDIES

Variable	Average Value	Minimum	Maximum
Group sample size 1	55,2	25	98
Group sample size 2	60,3	28	102
Media group 1	78,5	58	99,5
Media group 2	71,2	52,3	97,8
Group standard deviation 1	8,8	4,8	13,5
Group standard deviation 2	9,2	4,9	14
d de Cohen	0,8	0,55	1,02

[a] Own elaboration

Figures 1–6 illustrate effect sizes, publication bias, and data distribution. The forest plot (Fig. 1) shows study-level effect sizes, and the funnel plot (Fig. 2) indicates minimal publication bias with symmetrical point dispersion. Figures 3–4 display effect size distributions, with most Cohen's d values between 0.5 and 0.8, reflecting consistent positive impacts of Industry 4.0 and 5.0 technologies on nanostore operational performance and supply chain efficiency. Figure 5 confirms strong, reliable benefits (Cohen's d = 0.8). Figure 6 demonstrates consistent effect sizes across sample sizes, reinforcing the meta-analysis reliability.

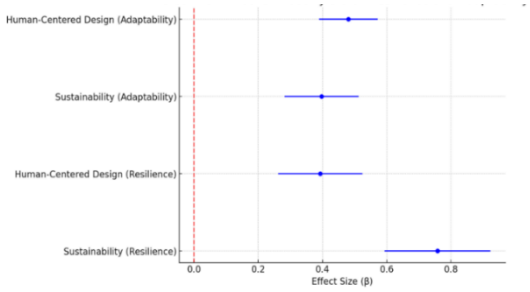

Fig. 1 Forest diagram of effect sizes
[a] Own elaboration

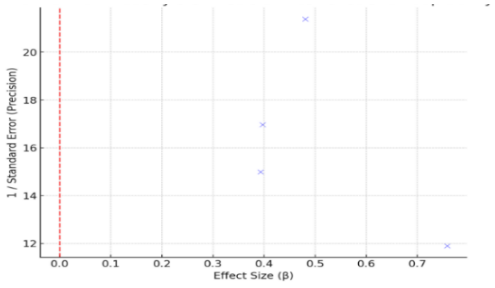

Fig. 2 Funnel Plot: Evaluation of bias in Industry 5.0
[a] Own elaboration

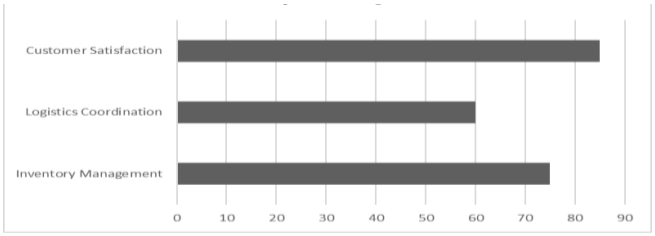

Fig 3. Percentage Impact Distribution
[a] Own elaboration

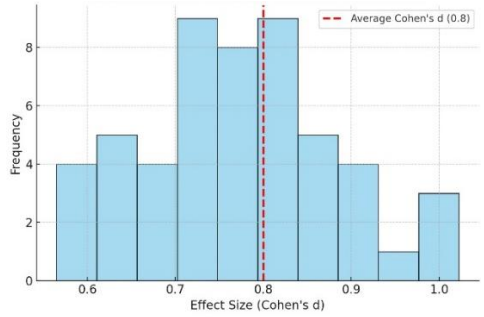

Fig. 4 Effect size chart
[a] Own elaboration

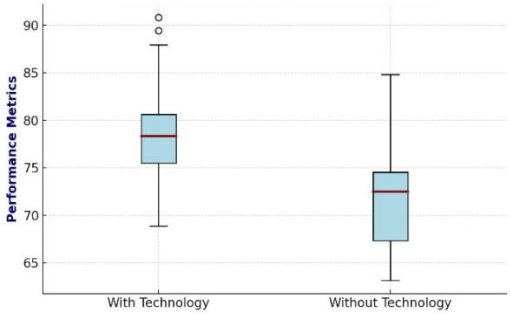

Fig. 5 Comparison graph of means between groups.
[a] Own elaboration

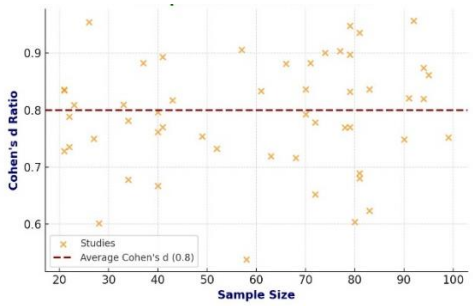

Fig. 6 Dispersion of the effect
[a]Own elaboration

B. *Heterogeneity Analysis*

Cochran's Q test ($Q = 10.64$, $p < 0.01$) and I^2 statistic (81.18%) indicate substantial heterogeneity. Contextual differences, such as regional economic conditions, methodological variability, and a restricted focus on Latin America and the Middle East, contribute to these variations. Standardizing methodologies and expanding geographical scope could reduce heterogeneity and improve generalizability. Future research should explore how store size, digital adoption, and location impact these findings.

C. *Publication Bias Assessment*

Egger's test ($p = 0.711$) and the funnel plot suggest minimal publication bias. The consistent Cohen's $d = 0.8$ confirms a moderate to large effect, reinforcing the importance of technology adoption across different study conditions.

D. *Results*

The meta-analysis supports two propositions:

1) Proposition 1: Industry 4.0 technologies significantly improve nanostore supply chain performance (Cohen's $d = 0.8$), particularly in:

- Inventory management ($d = 0.92$)
- Customer satisfaction ($d = 0.84$)
- Logistics coordination ($d = 0.76$)
- Overall impact: 68% improvement in operational efficiency

2) Proposition 2: Industry 5.0 technologies enhance resilience and adaptability through sustainability and human-centered design:

- Resilience ($R^2 = 0.516$)
- Adaptability ($R^2 = 0.581$)

E. *Data on Document Inclusion and Exclusion*

Of 300 initial studies, 52 met inclusion criteria, while others were excluded due to irrelevance to nanostores or focus on large-scale retailers.

Table II categorizes the studies based on the technologies examined (Industry 4.0 and Industry 5.0) and their methodological quality. This table provides insight into the distribution of studies, helping to contextualize the findings by technological focus and quality of research methodology.

TABLE II
CLASSIFICATION OF INCLUDED STUDIES

Category	Number of Studies
Industry 4.0	30
Industry 5.0	22
Methodological Quality	High: 32, Medium: 20

[a] Own elaboration

F. *Critical Evaluation*

Higher methodological quality correlated with more reliable effect size estimates. However, small sample sizes and potential confounding factors should be considered in interpretation.

G. *Discussion*

1) Interpretation of Results: Both Industry 4.0 and 5.0 technologies positively influence nanostore supply chains, enhancing efficiency, inventory management, and customer satisfaction. The limited geographical scope, focusing on Latin America and the Middle East, suggests caution in generalizing findings globally. Expanding research to include regions such as Asia and Africa, as well as exploring emerging Industry 5.0 technologies like advanced robotics and digital twins, could provide deeper insights into their scalability and impact.

Table III summarizes how sustainability and human-centered design impact resilience and adaptability. Sustainability strongly influences resilience ($\beta = 0.7583$), while

human-centered design has a stronger effect on adaptability (β = 0.4807).

TABLE III
Interpretation of results - visual summary

Causal Variable	Outcome Variable	Beta Coefficient (β)	Standard Error	p-Value	R^2
Sustainability	Resilience	0,7583	0,1	< 0.001	0,516
Human-Centered Design	Resilience	0,3928	0,12	< 0.001	0,516
Sustainability	Adaptability	0,3973	0,11	< 0.001	0,581
Human-Centered Design	Adaptability	0,4807	0,09	< 0.001	0,581

[a] Own elaboration

2) Relevance to Research Questions and Objectives: Findings confirm that:

Industry 4.0 enhances nanostore performance.

Industry 5.0 improves sustainability and adaptability.

H. Implications for Theory and Practice

1) Theoretical Implications: The study supports the integration of sustainability and human-centered design in technological adoption for nanostores. Future research should explore their intersection as drivers of performance.

2) Practical Implications: Nanostores should prioritize Industry 4.0 and 5.0 technologies for operational efficiency, customer satisfaction, and competitive advantage. Aligning technological initiatives with sustainability can enhance long-term success.

I. Contribution to Existing Literature

This study bridges the gap in research by highlighting how small-scale retailers can effectively adopt Industry 4.0 and 5.0 technologies. Unlike prior research that focused on large firms, this analysis demonstrates how nanostores benefit from technological integration [38-42].

Fig. 7 illustrates the adoption trend from 2018–2024, showing steady growth followed by accelerated adoption, particularly with Industry 5.0's focus on adaptability and sustainability.

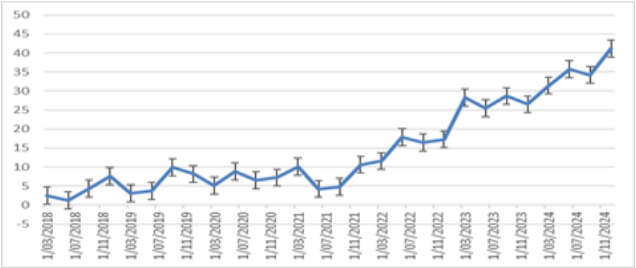

Fig. 7 Trend of technological adoption
[a]Own elaboration

V. Conclusions

A. Key Findings and Contributions

This study aimed to evaluate the impact of Industry 4.0 and Industry 5.0 technologies on nanostore supply chains through a meta-analysis of 52 recent studies. The analysis revealed that both Industry 4.0 and Industry 5.0 technologies positively affect Nanostore Supply Chain Performance, with an overall moderate to large effect size of d=0.8

This study demonstrates that both Industry 4.0 and 5.0 technologies have a significant positive impact on nanostore supply chains, improving operational performance, inventory management, and customer satisfaction.

Both technologies contribute to greater adaptability and efficiency in supply chain operations, supporting the two key propositions of this study: enhancing technological adaptability and improving overall supply chain performance.

Industry 4.0 Technologies: The integration of technologies such as IoT, AI, and blockchain demonstrated significant improvements in operational efficiency, inventory management, and customer satisfaction in nanostores. The findings confirm the anticipated benefits of these technologies, aligning with existing literature on their impact on Nanostore Supply Chain Performance.

Industry 5.0 Technologies: The incorporation of Industry 5.0 concepts, including human-centric design and sustainability, also showed a substantial positive effect on Nanostore Supply Chain Performance. This includes emerging technologies such as advanced robotics and digital twins, which offer potential for further enhancing logistics and supply chain resilience [410].

These results underscore the importance of adopting advanced technological solutions for small-scale retailers to stay competitive. The study contributes to the theoretical understanding of technology adoption in retail environments and offers practical insights for nanostores aiming to leverage these technologies. This aligns with previous work in the field, such as the study by [43], which highlighted the critical role of technology integration in improving nanostore performance in Latin American contexts.

Moreover, the findings emphasize the critical role of technological adaptability for small-scale retailers, which allows them to navigate both competitive pressures and market demands effectively, enabling them to optimize both short-term operations and long-term strategic goals.

The implementation of advanced technological solutions is a decisive factor for the competitiveness and sustainability of nanostores in the Latin American context. The effective integration of digital tools enables nanostores to optimize their supply processes, improve consumer interaction, and expand their marketing channels, which is particularly relevant given the structural challenges and informality that characterize this sector in the region [29].

The study highlights how technological adoption not only increases operational efficiency but also acts as a bridge toward structural transformation, aligning small businesses with Society 5.0 principles focused on inclusive digitization and social well-being. This approach serves as a strategic response to the pressure from large retail chains and evolving consumption habits, reaffirming that technological

development in nanostores is a key necessity for their market survival.

B. Limitations and Future Research Directions

1) Limitations: Study Quality and Variability: The meta-analysis included studies with varying methodological rigor, which could affect the reliability of the results. Some studies lacked detailed data or employed diverse methodologies, impacting the consistency of findings. In particular, some studies employed diverse research designs, such as qualitative case studies and quantitative surveys, which may have affected the comparability of their results.

Scope of Included Studies: The research focused on recent studies from the past two decades, potentially excluding earlier but relevant works. Additionally, the geographical focus primarily included studies from Latin America and the Middle East, limiting generalizability. Expanding the scope to include regions such as Asia and Africa could enhance global applicability [42].

Addressing these limitations by adopting more standardized methodologies and expanding the research to additional contexts could enhance the global applicability and capture the evolving impact of Industry 4.0 and 5.0 technologies over time.

2)Future Research Directions: Longitudinal Studies: Future research should consider longitudinal studies to assess the long-term impacts of technology adoption on nanostore supply chains. Future research should also explore the implications of emerging Industry 5.0 technologies, such as advanced robotics and digital twins, in logistics to gain deeper insights into their influence on Nanostore Supply Chain Performance [38].

Diverse Contexts: Expanding the research to include a broader range of geographic and cultural contexts can provide a more comprehensive understanding of technology impacts.

Methodological Advances: Employing more standardized methodologies across studies could enhance the comparability and reliability of results.

C. Managerial and Academic Implications

1) Managerial Implications:

For Practitioners: Nanostores can benefit from adopting Industry 4.0 and 5.0 technologies to improve their supply chain efficiency and sustainability practices. The practical insights provided can guide small-scale retailers in making informed decisions about technology investments. For example, implementing AI-driven inventory management could streamline operations and reduce stockouts, while IoT systems could improve real-time tracking of products.

For Policy Makers: Policymakers should support initiatives that facilitate the integration of advanced technologies in small retail businesses, potentially through funding or training programs. This process could be facilitated by offering grants for technology adoption or providing specialized training programs for small retailers.

2) Academic Implications:

Advancing Theory: The study adds to the theoretical discourse on technology adoption in retail environments by providing empirical evidence of the benefits and challenges associated with Industry 4.0 and 5.0 technologies.

Conceptual Contributions: The research offers a refined understanding of how these technologies impact Nanostore Supply Chain Performance, contributing to the development of theoretical frameworks in the field. It also opens avenues for future research to explore the integration of multiple technologies and their synergistic effects on nanostore supply chains, offering a more holistic view of the technological ecosystem, as by suggests [44].

D. Economic and Social Implications

1) Economic Implications:

Cost Efficiency: The adoption of advanced technologies can lead to cost savings through improved operational efficiencies and reduced waste.

Competitive Advantage: Small retailers that leverage these technologies may gain a competitive edge, potentially leading to increased market share and profitability. This digital transformation is essential for nanostores to compete against larger retailers with more substantial technological infrastructure, contributing to the economic resilience of small-scale businesses.

2) Social Implications:

Employment and Skills Development: The integration of advanced technologies may require new skills and training, impacting employment patterns and the need for reskilling in the retail sector.

Consumer Benefits: Enhanced Nanostore Supply Chain Performance can lead to better customer experiences, with improvements in product availability and service quality. Moreover, the integration of sustainable practices in Industry 5.0 technologies can appeal to increasingly conscious consumers, further boosting customer loyalty. However, the integration of advanced technologies might also contribute to workforce displacement in traditional roles, creating a need for policies to assist in workforce transitions.

E. Implications for Public Policies

Beyond the operational impact, the results have significant implications for the formulation of public policies. As highlighted [29] and [45], the effective utilization of Industry 4.0 and 5.0 technologies in microenterprises requires institutional support, particularly in the form of financing, technical training, and collaborative networks. This study reinforces these recommendations by demonstrating that technological adoption has tangible effects on nanostore performance. Therefore, it is suggested that policymakers design specific programs for this type of retail, considering its vital role in the informal economy and its structural vulnerability to abrupt technological changes.

F. Originality and Value of the Paper

This article offers a meta-analysis of Industry 4.0 and 5.0 technologies' impact on nanostore supply chains, synthesizing studies to highlight benefits and challenges. It provides practical recommendations for small-scale retailers and theoretical insights into digital transformation in informal retail ecosystems. The research enriches academic discourse, supports practitioners in adapting supply chains for competitiveness and sustainability, and addresses a gap by focusing on nanostores, an under-researched sector. It lays a foundation for future context-specific frameworks tailored to non-traditional retail models.

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