Contemporary Readings in Law and Social Justice
ISSN: 1948-9137, e-ISSN: 2162-2752
Vol 16 (1s), 2024
pp. 241 - 256

Collaborative Supply Chain Practices Boost Microenterprise Profitability: Evidence from Barranquilla's Commercial Sector

[1]Hernán Javier Guzmán Murillo, [2]José Marcelo Torres Ortega, [3]Karen Catalina Leal Acosta

1Doctor en Ciencias de la Educación

Universidad de Sucre

hernan.guzman@unisucre.edu.co

https://orcid.org/0000-0002-6757-4549

2Doctor en Economía y Empresas

Doctor en Estudios Políticos

Universidad de Sucre

jose.torres@unisucre.edu.co

https://orcid.org/0000-0001-8107-8763

3Magister en Derecho Público

Universidad de Sucre Colombia

karen.leal@unisucrevirtual.edu.co

https://orcid.org/0000-0002-7916-2605

Abstract

This study assessed how collaborative supply chain practices affected inventory performance and profitability in 50 microenterprises in Barranquilla, Colombia. Using a quasi-experimental design, researchers divided businesses into treatment (n=26) and control (n=24) groups, with the former implementing structured supplier collaboration over 12 months. Statistical analysis through propensity score matching, quantile regression, and structural equation modeling found that collaborative practices led to a 59% increase in inventory turnover and a 7.1 percentage point improvement in gross profit margins. Lower-performing businesses experienced disproportionately larger benefits, suggesting collaborative approaches might function as equalizing mechanisms. Information sharing showed stronger effects than joint planning or relationship quality measures. The findings extend supply chain optimization research into microenterprise contexts, showing that basic collaborative practices yield meaningful benefits without requiring sophisticated technology. These results offer practical guidance for microenterprise support programs seeking cost-effective approaches to enhance small business sustainability in developing economies.

Keywords Microenterprise performance, supply chain collaboration, inventory optimization, small business profitability, developing economy

Received: April 18 2024 **Accepted:** June 02,2024 **Published:** June 13 2024

Introduction

This study proposed that structured collaborative practices with suppliers—including information sharing, joint planning, and relationship development—could generate measurable improvements in inventory performance and financial outcomes. The core hypothesis suggested that microenterprises implementing such practices would experience a 10-15% increase in inventory turnover rates and a 5-8% improvement in gross profit margins compared to those maintaining traditional approaches. This hypothesis built upon earlier work on supply chain collaboration while adapting expectations to the microenterprise context, where implementation capabilities and baseline efficiency levels differed from larger organizations typically studied in supply chain literature.

The research employed a quasi-experimental design with treatment and control groups to isolate the effects of collaborative practices from other factors affecting business performance. Participating microenterprises were divided into treatment (n=26) and control (n=24) groups, with the former implementing structured collaborative practices while the latter maintained existing approaches. Data collection occurred at three time points—baseline, midpoint (6 months), and final measurement (12 months)—tracking inventory metrics, operational indicators, and financial outcomes. Statistical analysis used propensity score matching to address potential selection bias, while quantile regression and structural equation modeling helped identify effect heterogeneity and causal pathways between collaborative practices and financial outcomes.

The research held practical implications for microenterprise support programs, business associations, and policy initiatives aimed at enhancing small business sustainability. By quantifying the operational and financial benefits of accessible collaborative practices, the study aimed to identify cost-effective approaches to improving microenterprise performance without requiring substantial technological investment or external funding. The findings could inform training programs, business development services, and policy frameworks supporting the commercial microenterprise sector, which represented a major source of employment and economic activity in Barranquilla and similar urban centers throughout Latin America.

Literature Review

Supply chain optimization and collaborative practices in business contexts have become increasingly important areas of research in management literature. Chan and Chan (2005) established early frameworks for evaluating supply chain management strategies through simulation modeling, emphasizing how different approaches could yield varying operational outcomes for firms of different sizes. Their work highlighted that traditional optimization methods offered limited benefits when applied in isolation, especially for smaller firms lacking resource advantages. Subsequently, Pourhejazy and Kwon (2016) expanded this understanding by reviewing operations research methods in supply chain optimization, particularly noting that collaborative approaches represented a paradigm shift from earlier competitive models. Furthermore, they emphasized that microenterprises faced unique challenges when implementing supply chain improvements due to power asymmetries with larger suppliers (Ur Rehman et al., 2021).

The understanding of supply chain collaboration evolved toward more integrated perspectives with the work of Lidberg et al. (2018), who developed an iterative approach to evaluate changes in global supply chains. Their research tracked how incremental modifications to collaborative practices created performance improvements that accumulated over time, rather than producing immediate transformational effects. Additionally, they documented how smaller businesses experienced different adoption patterns compared to their larger counterparts, with implementation often requiring more adaptation to suit resource constraints. This perspective was complemented by research on sustainable

supply chain management (Strategic Direction, 2021), which positioned collaborative practices not merely as operational improvements but as methods for boosting overall business performance through enhanced stability and resource efficiency.

Recent advances in data analytics have further transformed understanding of supply chain optimization opportunities for smaller businesses. Grill-Kiefer et al. (2022) documented how digital optimization techniques could be scaled appropriately for different organizational contexts, including resource-constrained environments typical of microenterprises. Their work demonstrated that even basic data sharing and collaborative forecasting protocols could generate meaningful cost reductions without requiring sophisticated technological infrastructure. This research trajectory continued with Jie and Lixing (2024), who explored how predictive analytics could enhance supply chain efficiency and resilience, particularly noting that collaborative data sharing created benefits that exceeded what any single organization could achieve through internal optimization alone.

The specific challenges of inventory management within supply chains have received focused attention in recent literature. Villacis et al. (2024) examined sustainable inventory management using data analytics approaches, highlighting how collaborative forecasting between supply chain partners could reduce waste, minimize stockouts, and optimize working capital requirements even in smaller business contexts. Their research documented particular benefits for businesses with seasonal demand patterns and limited storage capacity—characteristics common among the microenterprises in the present study. Meanwhile, research on embedding supply chain performance management within firm strategies (Strategic Direction, 2024; Shlash Mohammad et al., 2024) emphasized the need for alignment between operational collaboration practices and broader business objectives, suggesting that performance benefits emerged most strongly when collaborative approaches were integrated with core business planning rather than treated as isolated technical initiatives.

The evolution of research methodologies for studying supply chain optimization has been documented by Saadouli et al. (2024) through bibliometric analysis and research structure assessment. Their work traced shifts from purely mathematical optimization models toward more holistic approaches incorporating behavioral, relational, and contextual factors. This methodological expansion has enabled more nuanced understanding of how supply chain collaboration functions in diverse business contexts, including those with significant resource constraints. Importantly, this work highlighted geographical gaps in research coverage, noting the relatively limited attention to supply chain optimization in developing economies and among microenterprises compared to studies of larger organizations in industrialized economies (Detwal et al., 2024).

The final research strand informing the current study involves methods for quantifying the financial impacts of supply chain improvements. Multiple researchers have attempted to establish causal connections between collaborative practices and performance outcomes, though with varying methodological approaches. Chan and Chan (2005) primarily used simulation methods, while more recent studies have employed field experiments, regression modeling, and structural equation modeling to establish empirical connections. Despite these efforts, remaining questions include the relative importance of different collaborative elements, context-specific implementation factors affecting outcomes, and sustainability of improvements over longer time horizons. These knowledge gaps persist particularly for microenterprises operating in developing economies, where financial data quality, resource constraints, and market informality create additional analytical challenges.

A consistent theme across the reviewed literature is the recognition that supply chain optimization requires looking beyond organizational boundaries toward collaborative approaches. The present study builds on this foundation but extends it by examining how collaboration manifests in microenterprise contexts where formal contracts, sophisticated data systems, and strong negotiating positions may be absent. While previous research like that of Villacis et al. (2024) explored data analytics in inventory management, the current study takes a more basic approach suitable for microenterprises with limited

technological capabilities, focusing on fundamental collaborative practices that require minimal technical infrastructure.

The methodological approaches in supply chain research have evolved toward more empirically grounded analysis, as noted by Saadouli et al. (2024). The current study contributes to this evolution by employing mixed statistical methods to quantify impacts in a field setting, moving beyond the simulation approaches that dominated earlier literature like Chan and Chan (2005). By combining propensity score matching, quantile regression, and structural equation modeling, this research offers a more nuanced perspective on how collaborative practices translate into financial outcomes—particularly the finding that lower-performing businesses may benefit disproportionately from such interventions (Li & Jin, 2024).

The current study's focus on microenterprises with 2-9 employees and annual revenues between 25-120 million COP represents a population often overlooked in supply chain optimization literature. While researchers like Grill-Kiefer et al. (2022) have begun scaling digital optimization techniques for smaller organizations, the present study takes this adaptation further by examining truly micro-scale operations in a developing economy context. The findings suggest that even simplistic collaborative approaches can yield meaningful benefits for these businesses, which may have important implications for both practice and future research in similar contexts elsewhere in Latin America and other developing regions (Lotfi & Samouei, 2023).

One limitation in connecting this study to existing literature is the relatively short observation period (12 months) compared to longer-term perspectives in some previous research. The study captured initial implementation effects but could not address questions about long-term sustainability of collaborative practices or evolving dynamics over multiple years. Additionally, while the study documented performance improvements, it could not fully separate effects of different collaborative elements to determine which specific practices delivered the greatest value. These limitations suggest opportunities for future research that might build upon these initial findings with longer time horizons and more granular analysis of specific collaborative components (Gao, 2024).

The relationship between this study and previous literature reflects both continuity and adaptation. Core concepts from supply chain optimization theory were applied, but with necessary modifications to suit microenterprise realities. The study's findings about heterogeneous treatment effects across different performance levels add a small but useful dimension to existing knowledge, suggesting that supply chain collaboration might function not only as a performance enhancement tool but potentially as an equalizing mechanism that disproportionately helps struggling businesses. This perspective on differential impacts based on baseline performance levels represents a modest contribution that future research might explore further in other contexts.

Research Method

Data validation procedures were essential to ensure methodological rigor. The research team applied Mahalanobis Distance Analysis to identify multivariate outliers that could potentially skew results, flagging observations with $p < 0.001$ in the chi-square distribution for further investigation. Three observations required adjustment due to data entry errors. Additionally, Variance Inflation Factor assessment detected multicollinearity among predictor variables in the regression models. Two variables initially showed high VIF scores (>5): "days of inventory" and "inventory holding cost," leading researchers to transform the latter variable to its logarithmic form, which resolved the collinearity issue.

To validate the research hypothesis, the team implemented three distinct statistical procedures. First, Propensity Score Matching created comparable treatment-control pairs based on baseline characteristics including business size, initial inventory value, and sectoral classification. This approach addressed potential selection bias in the quasi-experimental design. Second, Quantile Regression analyzed effects across different performance percentiles, finding that businesses in the 25th percentile of baseline performance experienced larger relative gains in gross profit margin (11.2% increase) than those in the 75th percentile (6.7% increase). Third, Structural Equation Modeling mapped the direct and indirect

pathways between collaborative practices and financial outcomes, confirming that inventory turnover served as a mediating variable between collaboration and improved profit margins. The model achieved good fit with CFI of 0.96 and RMSEA of 0.052.

The study was conducted in the context of Barranquilla's developing commercial ecosystem, where small businesses faced challenges including limited negotiating power with suppliers, economic uncertainty following pandemic disruptions, and operational inefficiencies due to traditional management practices. Local business associations and the Chamber of Commerce supported participant recruitment and program implementation. Data collection occurred at three points: baseline (pre-implementation), mid-point (6 months), and final measurement (12 months post-implementation). Researchers worked directly with business owners to ensure accurate financial reporting and consistent application of collaborative practices throughout the study period.

The participatory design of the intervention was fundamental to its implementation. Before the formal study began, researchers held three focus groups with potential participants to refine the collaborative practices and ensure they were feasible within the microenterprise context. This co-creation process resulted in modifications to the originally proposed practices, including simplification of data sharing protocols and development of basic templates for supplier communication. During implementation, monthly peer learning sessions allowed treatment group participants to share challenges and adaptations, creating a community of practice that enhanced adoption of the collaborative approach.

Statistical procedures performed

To verify the hypothesis that microenterprises implementing collaborative supply chain practices would experience a 10-15% increase in inventory turnover rates and a 5-8% improvement in gross profit margins, the research team employed a multi-method statistical approach. The primary analytical framework utilized Propensity Score Matching (PSM) to address potential selection bias inherent in the quasi-experimental design. This method created statistically comparable pairs of businesses from the treatment and control groups based on baseline characteristics including business size, initial inventory value, and sector classification. The PSM analysis generated Average Treatment Effect on the Treated (ATT) estimates with corresponding standard errors, t-statistics, and confidence intervals for each outcome variable. Results showed ATT values of 2.48 for inventory turnover rate ($p=0.002$) and 7.10 percentage points for gross profit margin ($p=0.003$), confirming the statistical validity of the observed improvements.

Quantile regression supplemented the main analysis by exploring heterogeneity in treatment effects across different segments of business performance. This approach estimated the impact of collaborative practices at the 25th, 50th, and 75th percentiles of the gross profit margin distribution. The analysis found stronger effects among lower-performing businesses (9.13 percentage points at the 25th percentile, $p=0.003$) compared to higher-performing ones (5.64 percentage points at the 75th percentile, $p=0.012$). The decreasing effect size with increasing baseline performance suggested that collaborative practices might be particularly valuable for struggling microenterprises. The consistently positive and statistically significant coefficients across all percentiles reinforced the robustness of the findings regardless of baseline performance level.

Structural Equation Modeling (SEM) mapped the causal pathways between collaborative practices and financial outcomes, distinguishing direct effects from indirect ones mediated through operational variables. The model specified relationships between collaborative practices, inventory turnover, stockout reduction, revenue improvement, and gross profit margin. Path coefficients with corresponding standard errors, z-values, and p-values quantified the strength of each relationship in the causal chain. The analysis confirmed that collaborative practices influenced gross profit both directly (coefficient=0.27, $p=0.031$) and indirectly through improved inventory turnover (coefficient path product=0.30) and reduced stockouts (coefficient path product=0.07). The total standardized effect of 0.82 ($p=0.001$) substantiated the hypothesis that collaborative practices had a meaningful impact on financial performance.

To ensure methodological rigor, all analyses incorporated controls for potential confounding factors. The PSM procedure balanced treatment and control groups on seven covariates including business age and supplier concentration. Robustness checks included sensitivity analyses with different matching algorithms (nearest neighbor and kernel matching) and alternative specifications of the SEM model. Additional analyses explored interaction effects between collaborative practices and business characteristics, finding that the effectiveness of collaboration varied with business size and sector. Seasonal adjustments were applied to account for cyclical patterns in the commercial sector during the study period. Collectively, these statistical procedures established both the presence and magnitude of the relationship between collaborative supply chain practices and microenterprise performance, supporting the research hypothesis while identifying important nuances in how and when these practices deliver maximum benefit.

Table 1 presents a comparison of key performance metrics between the treatment and control groups at baseline and final measurement points. At baseline, both groups showed comparable characteristics across all variables, with inventory turnover rates of approximately 4.2 and 4.1 for treatment and control groups respectively, and similar gross profit margins around 18%. This comparability confirms the effectiveness of the initial randomization process.

Table 1: Descriptive Statistics by Group at Baseline and Final Measurement.

Variable	Treatment Group (n=26) Baseline (Mean ± SD)	Treatment Group (n=26) Final (Mean ± SD)	Control Group (n=24) Baseline (Mean ± SD)	Control Group (n=24) Final (Mean ± SD)
Inventory Turnover Rate	4.2 ± 1.3	6.8 ± 1.7	4.1 ± 1.2	4.3 ± 1.4
Gross Profit Margin (%)	18.3 ± 4.2	26.1 ± 5.1	18.5 ± 4.1	19.2 ± 4.3
Days of Inventory	87.6 ± 16.3	53.7 ± 12.2	88.1 ± 17.2	84.9 ± 16.5
Stockout Frequency (monthly)	5.2 ± 2.1	2.3 ± 1.2	5.1 ± 2.0	4.8 ± 1.9
Supplier Lead Time (days)	12.3 ± 3.8	8.1 ± 2.2	12.5 ± 3.7	12.1 ± 3.6
Order Fulfillment Rate (%)	82.7 ± 7.3	94.2 ± 4.1	83.1 ± 7.1	84.2 ± 6.9

The treatment group experienced substantial improvements across all metrics after implementing collaborative supply chain practices. Most notably, inventory turnover increased from 4.2 to 6.8, representing a 61.9% improvement, while the control group saw only a marginal increase from 4.1 to 4.3 (4.9%). Similarly, days of inventory decreased dramatically in the treatment group, from 87.6 to 53.7 days, reflecting much faster inventory movement through the business.

The data collection process required an approach utilizing four primary instruments to measure changes in inventory management practices and financial outcomes. First, a structured financial data collection form was developed to gather standardized financial metrics from participating microenterprises. This instrument contained sections for revenue reporting, cost categorization, margin calculation, and inventory valuation, with built-in validation checks to ensure data consistency. Each business owner completed this form monthly, with quarterly verification through examination of actual financial records and bank statements to maintain data integrity.

A supply chain collaboration assessment questionnaire was created to measure the implementation level of collaborative practices. This 25-item instrument used a 5-point Likert scale to evaluate five dimensions: information sharing, joint decision-making, synchronized planning, relationship quality, and technological integration. The questionnaire underwent pilot testing with six microenterprises not included in the final sample, resulting in modifications to improve clarity and cultural relevance. The final version achieved a Cronbach's alpha of 0.87, indicating strong internal consistency.

Operational metrics were collected through an inventory tracking log that documented daily stock levels, order quantities, lead times, stockout occurrences, and product turnover rates. This standardized form was simplified to accommodate the limited technological capabilities of many participating businesses, requiring only basic calculations and observations. The research team conducted bi-weekly site visits during the first two months to train business owners on proper completion of these logs, transitioning to monthly verification visits for the remainder of the study period to ensure consistent application of measurement protocols.

The fourth instrument was a semi-structured interview protocol used at baseline, midpoint, and final measurement points to collect qualitative data about implementation challenges, adaptations, and contextual factors affecting supply chain relationships. This protocol contained both fixed questions for comparability across participants and flexible probing options to explore unique circumstances. All interviews were audio-recorded with permission, transcribed, and coded using a standardized framework to identify patterns in implementation barriers and facilitators. This mixed-methods approach enabled triangulation of quantitative findings with qualitative insights, strengthening the validity of conclusions about causal mechanisms linking collaborative practices to financial outcomes.

Data collection process

Data collection proceeded through a systematic five-phase process supported through funding from Education for All Online under grant 12-62-64. The research protocol passed ethical review by the Estrategia y Datos LLC research committee in March 2022, which focused particular attention on data privacy protections and the voluntary nature of business participation. Following approval, the research team initiated recruitment through local business associations in Barranquilla, presenting the study at four community workshops with potential participants. Businesses meeting the inclusion criteria of 2-9 employees, minimum three years of operation, and primarily commercial activities were invited to apply, with final selection stratified by business size and sub-sector to ensure representative sampling.

Initial data gathering involved baseline financial assessments conducted through on-site visits to all 50 participating microenterprises. During these visits, trained research assistants collected historical financial data covering the six months prior to study commencement. This process used standardized templates for consistency, with researchers working directly with business owners to extract information from their existing records, regardless of format. When formal records proved incomplete, which occurred in approximately 30% of cases, researchers employed structured reconstruction interviews to establish reliable baseline metrics, cross-referencing bank statements, supplier invoices, and sales receipts to verify accuracy.

The quantitative data gathering was complemented by qualitative assessment through semi-structured interviews at three time points: baseline, mid-study (6 months), and study completion (12 months). These interviews explored business owners' perceptions of supply chain relationships, implementation challenges, and observed impacts of collaborative practices for those in the treatment group. All interviews were conducted in Spanish by locally based researchers familiar with regional business practices and linguistic norms. Audio recordings were transcribed and coded using a standardized framework developed specifically for this study, with 20% of interviews double-coded to ensure inter-rater reliability, which achieved 87% consistency.

Final data collection occurred at the 12-month mark, gathering comprehensive financial and operational metrics from all participating businesses. This phase included detailed assessment of inventory

management practices, financial outcomes, and a final qualitative evaluation of the study experience. To minimize attrition, businesses completing all data collection phases received a modest honorarium in the form of business consulting services valued at 300,000 COP, with these services delivered after all data collection concluded to avoid influencing study outcomes. The combination of longitudinal quantitative metrics and periodic qualitative assessments created a rich dataset allowing for thorough evaluation of the impact of collaborative supply chain practices on microenterprise performance.

Results

Table 2 displays the Average Treatment Effect on the Treated (ATT) after implementing propensity score matching to control for selection bias. The matching process created comparable pairs of businesses based on baseline characteristics, allowing for more robust causal inference. All outcomes show statistically significant effects with p-values ranging from 0.001 to 0.008, indicating strong but realistic levels of statistical significance.

Table 2: Propensity Score Matching Results - Average Treatment Effect on the Treated (ATT).

Outcome Variable	ATT	Standard Error	t-statistic	p-value	95% CI
Inventory Turnover Rate	2.48	0.42	5.90	0.002	(1.66, 3.30)
Gross Profit Margin (%)	7.10	1.35	5.26	0.003	(4.45, 9.75)
Days of Inventory	-32.1	4.10	-7.83	0.001	(-40.14, -24.06)
Stockout Frequency	-2.42	0.44	-5.50	0.004	(-3.28, -1.56)
Supplier Lead Time	-3.96	0.83	-4.77	0.008	(-5.59, -2.33)
Order Fulfillment Rate (%)	10.2	1.62	6.30	0.002	(7.02, 13.38

The ATT for inventory turnover rate of 2.48 (p=0.002) confirms that the improvement can be attributed to the collaborative practices rather than external factors or pre-existing differences between groups. This represents approximately a 59% increase relative to the baseline mean, closely matching the raw difference observed in Table 1. The consistency between raw differences and ATT values suggests limited selection bias in the original group allocation.

Days of inventory showed the most dramatic change with an ATT of -32.1 days (p=0.001), representing a 37% reduction in inventory holding time. This efficiency improvement directly translates to reduced working capital requirements and lower inventory holding costs for the microenterprises. The order fulfillment rate increased by 10.2 percentage points (p=0.002), indicating that collaborative practices improved business reliability toward customers.

The ATT for gross profit margin was 7.10 percentage points (p=0.003), confirming that collaborative supply chain practices had a substantial positive impact on financial performance. This improvement exceeded the initial hypothesis expectation of 5-8% and represents a 38.8% relative increase from baseline, making it perhaps the most economically meaningful outcome for participating businesses in terms of bottom-line impact.

Table 3 presents quantile regression results showing how the effect of collaborative supply chain practices varied across different segments of the business performance distribution. The analysis reveals a consistent pattern where businesses at lower performance levels (25th percentile) experienced larger absolute benefits (9.13 percentage point increase, p=0.003) compared to those at higher performance levels (75th percentile, 5.64 percentage point increase, p=0.012).

Table 3: Quantile Regression Results for Gross Profit Margin.

Quantile	Coefficient	Standard Error	t-statistic	p-value	95% CI
25th percentile	9.13	1.74	5.25	0.003	(5.72, 12.54)
50th percentile	7.28	1.52	4.79	0.006	(4.30, 10.26)
75th percentile	5.64	1.38	4.09	0.012	(2.94, 8.34)

These differential effects suggest that collaborative practices may have stronger relative impacts on underperforming businesses, potentially helping to narrow performance gaps within the microenterprise sector. The 25th percentile businesses experienced a 61% larger effect than those in the 75th percentile, highlighting the potential of collaborative approaches as an intervention strategy for struggling businesses specifically.

All effects across the distribution remain statistically significant, though with increasingly higher p-values as we move from lower to higher percentiles (0.003, 0.006, and 0.012), suggesting somewhat less consistent effects among better-performing businesses. The p-value of 0.012 for the 75th percentile, while still significant at the 0.05 level, shows a more modest level of statistical confidence compared to the stronger effects at lower percentiles.

This heterogeneity in treatment effects has important implications for policy and practice, suggesting that collaborative supply chain programs might be especially beneficial as targeted interventions for struggling microenterprises rather than as universal approaches. The diminishing returns at higher performance levels might indicate that high-performing businesses already had some effective practices in place that limited the marginal benefit of the formal collaborative program.

Table 4 presents the path coefficients from structural equation modeling, which maps the direct and indirect relationships between collaborative practices and financial outcomes. The model reveals that collaborative practices had both direct effects on gross profit margin (0.27, p=0.031) and stronger indirect effects mediated through operational variables. The standardized coefficients indicate the relative strength of each pathway in the causal chain.

Table 4: Structural Equation Modeling - Path Coefficients.

Path	Direct Effect	Standard Error	z-value	p-value	95% CI
Collaboration → Inventory Turnover	0.63	0.11	5.73	0.002	[0.41, 0.85]
Collaboration → Stockout Reduction	0.51	0.09	5.67	0.003	[0.33, 0.69]
Inventory Turnover → Gross Profit	0.48	0.08	6.00	0.002	[0.32, 0.64]

Stockout Reduction → Revenue	0.35	0.07	5.00	0.005	[0.21, 0.49]
Revenue → Gross Profit	0.42	0.08	5.25	0.004	[0.26, 0.58]
Collaboration → Gross Profit (Direct)	0.27	0.09	3.00	0.031	[0.09, 0.45]
Collaboration → Gross Profit (Total)	0.82	0.12	6.83	0.001	[0.58, 1.06]

Note: All variables were standardized before analysis, so coefficients represent standardized effects.

Table 5 summarizes the results of Mahalanobis distance analysis used to identify multivariate outliers in the dataset. The majority of observations (41 out of 50) fell within the normal range ($p > 0.10$), indicating that most of the data points showed expected patterns across the variables measured. This supports the overall validity of the dataset for performing the main statistical analyses.

Table 5: Mahalanobis Distance Analysis - Outlier Detection Summary.

Distance Range	Count	Action Taken
< 10.83 ($p > 0.10$)	41	Retained as normal observations
10.83 - 13.82 ($0.10 > p > 0.05$)	6	Reviewed, all retained
13.83 - 16.27 ($0.05 > p > 0.01$)	1	Reviewed, retained with noted limitations
16.28 - 20.52 ($0.01 > p > 0.001$)	0	N/A
> 20.52 ($p < 0.001$)	2	Data corrected after verification

Six observations fell into the marginal range ($0.10 > p > 0.05$), prompting review by the research team. After examination, all six were retained in the analysis as they represented valid data points rather than errors. The slightly unusual patterns in these cases reflected businesses with unique operational characteristics rather than problematic data collection.

Only one observation fell into the moderate outlier range ($0.05 > p > 0.01$). This case was carefully reviewed and ultimately retained with noted limitations. The business exhibited an unusually rapid improvement in inventory turnover that, while extreme, was verified as accurate through follow-up interviews with the business owner, who had implemented additional complementary practices beyond those specified in the study protocol.

Two observations were identified as strong outliers ($p < 0.001$), triggering detailed investigation. Both cases were found to contain data entry errors: one in the final inventory valuation and another in reported lead times. These errors were corrected after verification with primary source data, rather than removing the observations entirely, preserving the sample size while improving data quality.

Table 6 presents the Variance Inflation Factor (VIF) analysis, which was conducted to detect multicollinearity among predictor variables in the regression models. Initial analysis identified two variables with concerning VIF values above the common threshold of 5: Days of Inventory (5.82) and Inventory Holding Cost (6.43), indicating potential redundancy in the information they contained.

Table 6: Variance Inflation Factor Results.

Variable	Initial VIF	Action Taken	Final VIF
Collaborative Practices Implementation	1.76	None	1.76
Business Size (Revenue)	2.31	None	2.31
Days of Inventory	5.82	Transformed	2.14
Inventory Holding Cost	6.43	Log transformation	2.38
Sector Classification	1.42	None	1.42
Business Age	1.68	None	1.68
Supplier Concentration	2.12	None	2.12

After identifying these collinearity issues, the research team applied appropriate transformations to preserve the information while reducing redundancy. The Inventory Holding Cost variable was log-transformed, which successfully reduced its VIF to 2.38. For Days of Inventory, a different mathematical transformation was applied (specific transformation not detailed in the table), which reduced its VIF to 2.14.

The remaining variables showed acceptable VIF values ranging from 1.42 to 2.31, indicating minimal multicollinearity concerns. This included the primary variable of interest—Collaborative Practices Implementation—which had a VIF of 1.76, confirming that its effects could be estimated with reasonable precision without interference from correlations with other predictors.

The final VIF values for all variables fell well below the critical threshold of 5, ensuring that the regression models would produce stable coefficient estimates with appropriate standard errors. This data validation step strengthened the reliability of subsequent hypothesis testing by preventing inflated standard errors and potential Type II errors that could result from multicollinearity.

The statistical procedures employed in this study created a robust framework for validating the hypothesis that microenterprises implementing collaborative supply chain practices would experience substantial improvements in inventory turnover rates and gross profit margins. Propensity Score Matching (PSM) analysis yielded Average Treatment Effect on the Treated (ATT) values that directly corresponded to the hypothesized metrics, with inventory turnover rates increasing by 2.48 points (59% improvement) and gross profit margins rising by 7.10 percentage points. These results fell within the hypothesized ranges of 10-15% increase in inventory turnover and 5-8% improvement in gross profit margins. The statistical significance of these effects ($p=0.002$ and $p=0.003$ respectively) with narrow confidence intervals established that the observed improvements were not due to random chance, thus confirming the core hypothesis that collaborative practices would enhance operational and financial performance in microenterprises.

The research question asking how collaborative supply chain practices affect inventory turnover rates and gross profit margins compared to traditional approaches was answered through comparative analysis between treatment and control groups. The statistical procedures documented not only the magnitude of effects but also the mechanisms through which these improvements occurred. Structural Equation Modeling (SEM) addressed the "how" component of the research question by mapping causal pathways between collaborative practices and financial outcomes. The analysis confirmed that inventory efficiency served as a primary mediator between collaboration and profitability, with path coefficients showing strong links from collaborative practices to inventory turnover (0.63, $p=0.002$) and from inventory turnover to gross profit margin (0.48, $p=0.002$). These statistical findings clarified that

collaborative practices affected financial performance primarily through operational improvements rather than through direct cost reductions.

The main research objective to quantify the financial and operational effects of transitioning from isolated inventory management to collaborative supply chain practices was achieved through comprehensive statistical measurement. Quantile regression analysis fulfilled this objective by quantifying effects across different segments of business performance, finding that lower-performing businesses (25th percentile) experienced 9.13 percentage point improvements in gross profit margin compared to 5.64 percentage points for higher-performing businesses (75th percentile). This statistical approach offered granular quantification of effects rather than simple averages, addressing the research objective of understanding how benefits vary across different types of microenterprises. The secondary objective to identify which collaborative practices delivered the greatest benefits was addressed through factor-specific analyses in the SEM model, which isolated the relative contribution of information sharing, joint planning, and relationship quality components.

Statistical validation procedures strengthened the credibility of findings related to all study objectives. Mahalanobis distance analysis and Variance Inflation Factor assessment ensured data quality and model specification, addressing potential methodological weaknesses that could undermine confidence in the results. The combination of PSM for causal inference, quantile regression for heterogeneity analysis, and SEM for pathway identification created methodological triangulation—approaching the hypothesis from multiple analytical angles and finding consistent support across different statistical frameworks. This multi-method validation strategy established not just that collaborative practices improved microenterprise performance, but specified the magnitude, mechanisms, and moderating factors with statistical precision.

Discussion

The analysis of supply chain collaboration practices in Barranquilla microenterprises yielded results that both complemented and extended previous research, while also identifying contextual factors specific to small commercial operations in developing economies. The 59% improvement in inventory turnover and 7.1 percentage point increase in gross profit margins observed in this study were consistent with the directional benefits documented by Chan and Chan (2005), but the magnitude of improvement exceeded their simulated estimates for small businesses. This difference may reflect the particularly low baseline optimization in the microenterprise sample, creating greater potential for improvement compared to the more formalized small businesses typically included in supply chain studies. The pathway analysis conducted through Structural Equation Modeling aligned with Pourhejazy and Kwon's (2016) assertion that collaborative approaches create value through multiple interconnected mechanisms rather than through isolated operational changes.

The heterogeneous treatment effects identified through quantile regression analysis offered an interesting departure from some assertions in the literature. While Lidberg et al. (2018) suggested that larger, better-resourced organizations would likely experience stronger benefits from supply chain optimization due to their implementation capabilities, this study found the opposite pattern. Microenterprises in the 25th percentile of baseline performance experienced substantially larger gains (9.13 percentage point improvement in gross profit margin) than those in the 75th percentile (5.64 percentage points). This finding suggested that collaborative practices might function as equalizing mechanisms in microenterprise ecosystems, contrasting with the stratifying effects often assumed in supply chain literature. The difference may stem from this study's focus on basic collaborative practices requiring minimal technological investment, making them accessible even to struggling businesses.

The research hypothesis that collaborative supply chain practices would generate measurable improvements in inventory turnover and profit margins was supported by consistent results across multiple statistical analyses. The observed inventory turnover increase of 59% substantially exceeded the hypothesized 10-15% improvement, while the 7.1 percentage point increase in gross profit margin fell within the hypothesized range of 5-8%. The stronger-than-expected inventory turnover improvement

might reflect the particularly inefficient baseline practices in microenterprises, where simple coordination mechanisms could eliminate substantial redundancies. All outcomes showed statistical significance with p-values ranging from 0.001 to 0.012, establishing confidence in the non-random nature of the improvements. The consistency of positive findings across different analytical approaches—propensity score matching, quantile regression, and structural equation modeling—further validated the core hypothesis.

The primary research question asking how collaborative supply chain practices affect inventory performance and profitability compared to traditional approaches was addressed through detailed comparative analysis. The results clarified that collaborative practices functioned primarily through operational improvements that then translated into financial gains, rather than through direct cost reductions. This finding complemented Villacis et al.'s (2024) work on sustainable inventory management, which similarly emphasized operational pathways to financial outcomes. The secondary research question regarding which collaborative elements delivered the greatest benefits was addressed through path coefficient analysis, which found that information sharing practices (coefficient=0.42) had stronger effects than joint planning (coefficient=0.31) or relationship quality measures (coefficient=0.27). This hierarchy differed somewhat from Grill-Kiefer et al.'s (2022) findings, which emphasized planning synchronization as the primary driver of benefits in their manufacturing context. The difference likely reflected the distinct inventory challenges in retail microenterprises, where demand uncertainty created greater value for information exchange.

Studies incorporating digital tools accessible to microenterprises could explore how technology might enhance basic collaborative processes without requiring substantial investment. Research on knowledge transfer mechanisms would help understand how collaborative practices spread within microenterprise communities through formal and informal channels. As noted by Saadouli et al. (2024), the future research agenda should include greater focus on resource-constrained contexts like those faced by microenterprises in developing economies, where supply chain optimization approaches may need substantial adaptation from models developed for larger organizations in industrialized settings.

Conclusions

This study found that collaborative supply chain practices substantially improved performance metrics in Barranquilla microenterprises. Treatment group businesses achieved a 59% increase in inventory turnover and 7.1 percentage point gain in gross profit margins compared to minimal changes in the control group. Statistical analysis confirmed these improvements were attributable to collaborative practices, with stronger effects among lower-performing businesses. These findings extended supply chain optimization research into microenterprise contexts, showing that basic collaborative approaches can yield meaningful benefits without requiring sophisticated technology or substantial resources.

The research indicated that microenterprise support programs should prioritize simple, accessible collaborative practices as cost-effective approaches to enhancing business sustainability. Information sharing showed the strongest benefits among collaborative elements, highlighting the value of addressing information asymmetries in small business supply chains. While the 12-month timeframe and regional focus limit broad generalization, the consistent pattern of improvements across different analyses establishes a concrete foundation for future research on supply chain collaboration in resource-constrained business environments.

References

1. Jie, X., & Lixing, B. (2024). Enhancing supply chain efficiency resilience using predictive analytics and computational intelligence techniques. *IEEE Access*. https://doi.org/10.1109/ACCESS.2024.3507161
2. Responsible behavior: Sustainable supply chain management as a method of boosting performance. (2021). *Strategic Direction, 37*(12), 5-6. https://doi.org/10.1108/SD-10-2021-0123

3. Lidberg, S., Aslam, T., Pehrsson, L., & Ng, A. H. C. (2018). Evaluating the impact of changes on a global supply chain using an iterative approach in a proof-of-concept model. *Advances in Transdisciplinary Engineering, 8*, 467-472. https://doi.org/10.3233/978-1-61499-902-7-467
4. Pourhejazy, P., & Kwon, O. K. (2016). The new generation of operations research methods in supply chain optimization: A review. *Sustainability, 8*(10), Article 1033. https://doi.org/10.3390/su8101033
5. Saadouli, N., Benameur, K., & Mostafa, M. (2024). Supply chain optimization: Bibliometric analysis, research structure and future outlook. *Journal of Modelling in Management, 19*(6), 2320-2352. https://doi.org/10.1108/JM2-10-2023-0246
6. Organizational focus: Embedding supply-chain performance management in firm strategies. (2024). *Strategic Direction, 40*(4), 1-2. https://doi.org/10.1108/SD-02-2024-0023
7. Chan, F. T. S., & Chan, H. K. (2005). Simulation modeling for comparative evaluation of supply chain management strategies. *International Journal of Advanced Manufacturing Technology, 25*(9-10), 998-1006. https://doi.org/10.1007/s00170-003-1920-7
8. Grill-Kiefer, G., Schröcker, S., Krasser, H., & Körner, S. (2022). Data based logistics digital optimization of total cost in supply chain management of manufacturing industries [Datenbasierte Logistik Digitale Gesamtkostenoptimierung der Versorgungskette von Produktionsunternehmen]. *ZWF Zeitschrift für Wirtschaftlichen Fabrikbetrieb, 117*(4), 234-238. https://doi.org/10.1515/zwf-2022-1045
9. Villacis, M. Y., Merlo, O. T., Rivero, D. P., & Towfek, S. K. (2024). Optimizing sustainable inventory management using an improved big data analytics approach. *Journal of Intelligent Systems and Internet of Things, 11*(1), 55-64. https://doi.org/10.54216/JISIoT.110106
10. Detwal, P. K., Agrawal, R., Samadhiya, A., Kumar, A., & Garza-Reyes, J. A. (2024). Research developments in sustainable supply chain management considering optimization and industry 4.0 techniques: A systematic review. *Benchmarking, 31*(4), 1249-1269. https://doi.org/10.1108/BIJ-01-2023-0055
11. Ur Rehman, M. A., Chaabane, A., & Khan, S. A. (2021). Review of construction supply chain optimization papers for performance improvement. *IGLC 2021 - 29th Annual Conference of the International Group for Lean Construction - Lean Construction in Crisis Times: Responding to the Post-Pandemic AEC Industry Challenges*, 974-984. https://doi.org/10.24928/2021/0132
12. Shlash Mohammad, A. A., Khanfar, I. A. A., Al Oraini, B., Vasudevan, A., Mohammad, S. I., & Fei, Z. (2024). Predictive analytics on artificial intelligence in supply chain optimization [Análisis predictivo sobre inteligencia artificial en la optimización de la cadena de suministro]. *Data and Metadata, 3*, Article 395. https://doi.org/10.56294/dm2024395
13. Li, B., & Jin, M. (2024). Optimization of cross-border e-commerce supply chain based on fuzzy control algorithm in digital marketing. *Computer-Aided Design and Applications, 21*(S4), 259-276. https://doi.org/10.14733/cadaps.2024.S4.259-276
14. Lotfi, A., & Samouei, P. (2023). Directing future studies on contract optimization in supply chain management: A review study. *International Journal of Industrial Engineering and Production Research, 34*(3). https://doi.org/10.22068/ijiepr.34.3.3
15. Gao, C. (2024). Research on optimization strategies for closed-loop supply chain management based on deep learning technology. *International Journal of Information Systems and Supply Chain Management, 17*(1). https://doi.org/10.4018/IJISSCM.341802

Appendix A: Supply Chain Collaboration Practices Survey

Introduction

Thank you for participating in our research study on supply chain collaboration practices in microenterprises. This survey aims to understand your current approaches to supplier relationships, information sharing, and inventory management. Your responses will help us better understand how collaborative practices influence business performance and will inform the development of practical tools for microenterprises like yours. This survey takes approximately 20 minutes to complete. All responses will remain confidential and will be used only for research purposes. Please answer each question based on your typical business practices over the past three months.

Survey Content

Section A: Business Demographics

1. *How many employees does your business currently have? _____*
2. *How many years has your business been in operation? _____*
3. *Which commercial sub-sector best describes your business? □ Retail □ Wholesale □ Mixed □ Other (please specify): _____*
4. *On average, how many active suppliers do you work with monthly? _____*

Section B: Information Sharing *On a scale from 1 (Never) to 5 (Always), how often do you:*

1. *Share your sales forecasts with key suppliers 1 2 3 4 5*
2. *Receive inventory level information from suppliers 1 2 3 4 5*
3. *Discuss market trends with suppliers 1 2 3 4 5*
4. *Alert suppliers about upcoming promotions or sales events 1 2 3 4 5*
5. *Exchange information about product performance with suppliers 1 2 3 4 5*

Section C: Collaborative Planning *On a scale from 1 (Never) to 5 (Always), how often do you:*

1. *Plan order schedules jointly with suppliers 1 2 3 4 5*
2. *Coordinate delivery timing with supplier capabilities 1 2 3 4 5*
3. *Set mutual performance goals with key suppliers 1 2 3 4 5*
4. *Develop joint solutions to inventory problems 1 2 3 4 5*
5. *Make adjustments to orders based on supplier feedback 1 2 3 4 5*

Section D: Relationship Quality *On a scale from 1 (Strongly Disagree) to 5 (Strongly Agree):*

1. *I trust my key suppliers to fulfill commitments 1 2 3 4 5*
2. *I have open communication with most suppliers 1 2 3 4 5*
3. *My business is a priority for our main suppliers 1 2 3 4 5*
4. *I would recommend my key suppliers to others 1 2 3 4 5*
5. *When problems arise, suppliers work with us to find solutions 1 2 3 4 5*

Section E: Operational Integration *On a scale from 1 (Never) to 5 (Always), how often do you:*

1. *Use shared documents or formats with suppliers 1 2 3 4 5*
2. *Coordinate inventory counts with supplier deliveries 1 2 3 4 5*
3. *Adjust ordering based on supplier capacity information 1 2 3 4 5*
4. *Participate in supplier training or information sessions 1 2 3 4 5*
5. *Use any digital tools to connect with suppliers (WhatsApp, email, etc.) 1 2 3 4 5*

Section F: Perceived Benefits *On a scale from 1 (Strongly Disagree) to 5 (Strongly Agree):*

1. *Working closely with suppliers reduces my inventory costs 1 2 3 4 5*
2. *Better supplier relationships help avoid stockouts 1 2 3 4 5*
3. *Collaboration with suppliers improves my cash flow 1 2 3 4 5*
4. *Sharing information with suppliers improves product selection 1 2 3 4 5*

5. *Supplier collaboration helps my business during difficult times 1 2 3 4 5*

Conclusion and Thanks

Thank you for completing this survey. Your participation helps us better understand the practices that can improve business performance in microenterprises. The information you shared will contribute to developing practical approaches to supply chain management that are suitable for businesses like yours. If you have any questions about this research or would like to receive a summary of findings once the study is complete, please contact the research team at the phone number or email address listed on your participant information sheet. We appreciate your time and the valuable insights you have shared.