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Estimativa da curva de custos e eficiência de escala em pequenas empresas: evidências de uma fabricante brasileira de móveis

Cost curve estimation and scale efficiency in small firms: evidence from a Brazilian furniture manufacturer

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Resumo: Este estudo estima curvas de custo e eficiência de escala por meio de uma análise longitudinal detalhada de uma fabricante de móveis brasileira. Aplicando uma abordagem integrada entre contabilidade e econometria a dados mensais (2019–2024), examina o comportamento dos custos durante a interrupção causada pela pandemia e a recuperação subsequente. Os resultados mostram aumento dos preços dos insumos e perdas de eficiência entre 2020 e 2021, seguidos por estabilização dos custos e recuperação parcial da eficiência até 2024, acompanhadas de um deslocamento para baixo da curva de custo médio. O estudo fornece um modelo replicável para a análise da dinâmica de custos em pequenas empresas sob choques externos, integrando a contabilidade gerencial à economia da produção. Destaca como a gestão adaptativa e o uso de ferramentas digitais podem restaurar a eficiência, oferecendo percepções práticas para gestores e formuladores de políticas em contextos de restrição de recursos.

Palavras-chave: Curva de custo; Pequenas empresas; Eficiência de escala; Recuperação pós-pandemia; Brasil.

Abstract: *This study estimates cost curves and scale efficiency using a detailed longitudinal analysis of a single Brazilian furniture manufacturer. Applying an integrated accounting–econometric approach to monthly data (2019–2024), it examines cost behavior through the pandemic disruption and subsequent recovery. Results show rising input prices and efficiency losses during 2020–2021, followed by cost stabilization and partial efficiency recovery by 2024, alongside a downward shift in the average cost curve. The study provides a replicable framework for analyzing cost dynamics in small firms under external shocks, bridging managerial accounting and production economics. It highlights how adaptive management and digital tools can restore efficiency, offering practical insights for managers and policymakers in resource-constrained settings.*

Keywords: *Cost curve; Small firms; Scale efficiency; Post-pandemic recovery; Brazil.*

Classificação JEL: D22; L25; M41; C51; L60.

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1. Introduction

The comprehension of cost structure and scale efficiency represents a central issue in microeconomic and managerial analyses. In small enterprises, however, the empirical estimation of cost behavior is often limited by data incompleteness, accounting inconsistencies, and managerial informality (SYVERSON, 2011; DE LOECKER; GOLDBERG, 2014).

While large corporations tend to rely on formalized production systems, small and medium-sized enterprises (SMEs) frequently base their decisions on intuition and short-term financial indicators rather than on analytical cost models, which hinders the optimization of production, pricing, and investment decisions (MAHLBERG et al., 2020; BLOOM et al., 2021). This disconnect between theoretical cost minimization models and practical cost behavior at the firm level continues to be an empirical gap in economic research.

The COVID-19 pandemic intensified such limitations, producing abrupt distortions in both production costs and demand. The furniture industry, predominantly composed of small firms, experienced a combination of input shortages, price inflation, and demand contraction between 2020 and 2021 (ABIMÓVEL, 2023; ZHANG et al., 2023).

As supply chains recovered, small manufacturers were compelled to restructure their cost systems and operational scales to restore competitiveness in the post-pandemic market (SWANSON; SANTAMARIA, 2021). Nonetheless, the literature remains scarce regarding how these structural shocks affected the curvature of cost functions and the efficiency patterns of small firms during recovery.

Given this context, this research seeks to answer the following question: How did the cost curve and scale efficiency of a small manufacturing firm evolve before, during, and after the COVID-19 pandemic?

To address this question, the study employs a quadratic cost function which allows the identification of the turning point of the average cost curve, thus quantifying the firm's scale efficiency across economic cycles. Using monthly accounting and production data from a Brazilian furniture manufacturer for the 2019–2024 period, the study empirically estimates total, average, and marginal costs and examines their evolution across market instability and recovery phases.

The main objective is to estimate the firm's cost curve and evaluate its scale efficiency, establishing empirical evidence of cost dynamics and productive adaptation in a real small business context. The study's relevance lies in expanding the empirical frontier of cost analysis to small firms, a segment with high social and economic relevance yet underrepresented in econometric research (MARTINS, 2018; KEE, 2007).

This paper offers three main contributions. First, it provides a methodological bridge between managerial accounting and production economics through an integrated model capable of reconstructing cost curves using real business data. Second, it presents longitudinal evidence on the structural adjustment of costs and efficiency following an exogenous shock, offering insight into the resilience of small firms. Third, it supports practical applications by illustrating how cost stabilization and operational scale can be regained through adaptive management, contributing to policies and practices aimed at improving productive efficiency in emerging economies.

2. Theoretical framework

The theoretical background supporting this study lies at the intersection of production economics and managerial accounting, particularly regarding the modeling of firm cost behavior and efficiency under changing market conditions. In economic theory, the cost function represents the technological relationship between input usage and output level, reflecting both production efficiency and the scale of operations (VARIAN, 1992; PINDYCK; RUBINFELD, 2018).

The traditional decomposition into total, average, and marginal costs enables the identification of optimal production levels and the presence of economies or diseconomies of scale. Recent empirical studies reaffirm that these cost structures remain central to productivity analysis, especially in the context of small firms facing resource constraints (CHEN et al., 2023; WHITE et al., 2024).

Empirically, estimating firm-level cost curves poses significant challenges, especially in small enterprises, due to the lack of disaggregated data and the coexistence of fixed and variable cost components influenced by managerial discretion (DE LOECKER et al., 2016; SYVERSON, 2011). Recent works emphasize that heterogeneity across firms, particularly in technology adoption and scale adjustment, directly affects cost curvature and efficiency patterns (BLOOM et al., 2021; BATTISTI; DARDANONI; DEMICHELIS, 2024).

The integration of accounting data into economic modeling thus becomes essential to better approximate real production behavior (KEE, 2007; MARTINS, 2018; LI, 2025). This approach aligns with the renewed empirical literature on microdata cost estimation, which stresses the need for hybrid methods combining firm-level accounting information and econometric estimation (ARDOLINO; BACCHETTI; IVANOV, 2022).

From a managerial accounting perspective, cost-volume-profit (CVP) analysis provides a simplified yet effective framework for evaluating how variations in sales volume, costs, and prices affect profitability and the firm's equilibrium (HORNGREN; SUNDEM; STRATTON, 2004).

Although traditionally applied in short-term planning, CVP analysis has evolved to accommodate dynamic environments and strategic cost management (GUO, 2022; KAPLAN; ATKINSON, 2022). This linkage between managerial indicators and economic efficiency has become increasingly relevant in post-pandemic contexts, where firms must simultaneously manage cost shocks, demand volatility, and productivity recovery (ARDOLINO; BACCHETTI; IVANOV, 2022; OECD, 2023).

In this study, the CVP framework serves as an empirical bridge to estimate the cost curve of a small manufacturing firm, capturing the structural distortions caused by the pandemic and the subsequent recovery of operational efficiency. This section develops the theoretical foundation for modeling and estimating cost curves in small firms. It begins with a review of classical cost theory, followed by a synthesis of empirical methods used in cost estimation, and concludes with the conceptual integration between CVP analysis and econometric modeling as applied in this research.

2.1. Cost theory and scale efficiency

The theory of production costs provides the analytical foundation for understanding how firms transform inputs into outputs under conditions of scarcity and technological constraint. The classical approach assumes that firms minimize production costs for a given level of output by balancing fixed and variable inputs to achieve efficiency (VARIAN, 1992; PINDYCK; RUBINFELD, 2018).

In this framework, total cost (TC) is decomposed into fixed cost (FC) and variable cost (VC), where FC remains constant regardless of output level, while VC varies directly with production. The functional form of cost curves reflects these relationships: total cost increases with output, while average cost (AC) and marginal cost (MC) typically display a U-shaped configuration, indicating economies and diseconomies of scale.

Recent studies refine this traditional view by showing that technological heterogeneity, input rigidity, and adjustment costs may distort the canonical U-shape of cost curves, particularly in small firms (CHEN et al., 2023; BATTISTI; DARDANONI;

DEMICHELIS, 2024). When fixed costs represent a substantial share of total costs, marginal adjustments in production can generate nonlinear behaviors in both AC and MC. These nonlinearities may arise from operational constraints, managerial capacity, or external shocks that restrict input flexibility (SYVERSON, 2011; BLOOM; BRYNJOLFSSON; FOSTER, 2021).

In small enterprises, where capital and labor are not perfectly substitutable, short-run cost structures tend to exhibit flatter average cost curves and steeper marginal cost segments, reflecting limited economies of scale (OECD, 2023).

Scale efficiency is achieved when the firm operates at the minimum point of its average cost curve—that is, when marginal cost equals average cost. At this level, the firm produces at its optimal scale of operation. However, empirical evidence indicates that small firms rarely reach this point due to financial constraints, lower technological intensity, and market uncertainty (WHITE et al., 2024).

In dynamic environments, the cost function evolves with learning effects, productivity growth, and external market pressures (BLOOM; BRYNJOLFSSON; FOSTER, 2021; OECD, 2023).

Empirical evidence also suggests that cost structures in SMEs are strongly influenced by digitalization and input price volatility (MAHLBERG et al., 2020; ZHANG et al., 2023). These factors affect not only production costs but also the shape and stability of cost curves, as digital technologies and supply chain adjustments can shift both average and marginal cost schedules downward when efficiency improves.

In post-pandemic contexts, cost and scale efficiency have been affected by disruptions in supply chains and input price volatility (ARDOLINO; BACCHETTI; IVANOV, 2022). Firms that successfully adapt to these conditions tend to internalize cost control mechanisms, diversify suppliers, and restructure production processes to mitigate inefficiencies. Such adaptive behaviors reshape the curvature of cost functions, promoting resilience and productivity gains.

Cost theory thus remains a cornerstone of production analysis, but its application to small firms requires recognizing their inherent constraints and adaptive processes. Examining cost curves and scale efficiency in these contexts provides valuable insights into how firms adjust operational strategies, allocate resources, and regain equilibrium in the face of economic shocks.

The next subsection builds on this foundation by reviewing empirical approaches to firm-level cost estimation and efficiency measurement.

2.2. Empirical evidence on firm-level cost estimation

Studies on firm-level cost estimation have become increasingly sophisticated as access to microdata and computational tools has expanded. Early models relied on aggregate data to estimate average cost structures, but firm-level analyses have revealed substantial heterogeneity in production efficiency, input flexibility, and cost dynamics (DE LOECKER et al., 2016; SYVERSON, 2011).

The literature emphasizes that cost curves vary across firms due to differences in management quality, technological adoption, and scale of operation (BLOOM et al., 2021; CHEN et al., 2023). These findings reinforce the importance of integrating microeconomic theory with detailed accounting data to derive realistic cost estimates.

Methodological advances have enabled the combination of econometric models and managerial accounting frameworks. De Loecker and Syverson (2021) demonstrate that productivity estimation and cost identification are interdependent, requiring precise measurement of markups and input elasticities. Kaplan and Atkinson (2022) argue that accounting systems enhance empirical cost models when variable and fixed cost classifications reflect economic behavior. This integration has produced hybrid approaches capable of capturing both the structural shape of cost curves and firm-specific adjustment processes, thereby linking theoretical and empirical perspectives.

The scientific literature has also incorporated analyses of firms affected by supply chain disruptions and macroeconomic shocks. Ardolino, Bacchetti and Ivanov (2022) find that manufacturing firms experienced temporary convexity in marginal costs during the COVID-19 pandemic due to input price volatility. The OECD (2023) reports that small firms restored efficiency by restructuring costs, digitalizing operations, and adopting adaptive learning after 2021. These observations reveal that cost functions evolve with managerial adaptation, technological renewal, and market recovery (WHITE et al., 2024).

Cost estimation techniques vary depending on data availability and research design. Parametric models, such as quadratic, Cobb-Douglas, and translog functions, remain suitable for single-firm or small-sample analysis (PINDYCK; RUBINFELD, 2018).

Nonparametric methods, including stochastic frontier and kernel regressions, offer flexibility to represent heterogeneous cost structures (BADIN; DALENOGARE; RODRIGUES, 2022). Battisti, Dardanoni and Demichelis (2024) apply continuous-treatment econometrics to assess how cumulative production experience alters marginal and average costs, demonstrating that learning effects can significantly reshape cost curvature.

In studies of small enterprises, accounting records often replace production data. This substitution can generate endogeneity and measurement bias, which may be addressed through instrumental variables or quasi-experimental corrections (GUO, 2022; CHEN et al., 2023).

When properly specified, such models allow for the estimation of cost slopes and the identification of each firm's position relative to its efficiency frontier. These insights are particularly relevant for developing economies, where small firms represent the majority of businesses but often face financial and technological constraints that limit scale efficiency (OECD, 2023; WHITE et al., 2024).

Empirical findings converge on the idea that cost dynamics are shaped by firm-specific characteristics, external shocks, and adaptive managerial strategies. The following section focuses on how these mechanisms manifest in small enterprises, emphasizing the relationship between resource constraints, cost control, and efficiency recovery in the post-pandemic context.

2.3. Cost analysis and efficiency in small firms

The analysis of production costs in small firms requires a multidimensional understanding of structural limitations, managerial practices, and market exposure. These firms generally operate with a higher proportion of fixed costs relative to total expenses, limited capacity to dilute administrative overheads, and greater sensitivity to fluctuations in input prices (OECD, 2023).

Consequently, their cost curves often present greater irregularity, and marginal costs exhibit stronger volatility as production levels change, which affects the ability to achieve scale efficiency and maintain profitability (BLOOM; BRYNJOLFSSON; FOSTER, 2021).

According to Chen et al. (2023), efficiency in small enterprises is influenced not only by scale but also by managerial capability. Firms that adopt formal cost management systems and integrate accounting information with operational decisions exhibit more stable cost structures and higher productivity.

Kaplan and Atkinson (2022) emphasize that the implementation of managerial accounting tools, such as activity-based costing and cost-volume-profit analysis, improves the capacity to identify inefficiencies and optimize resource allocation.

Conversely, firms that rely on informal control mechanisms tend to experience higher variability in performance and slower adjustments to changing market conditions (SYVERSON, 2011).

The post-pandemic period offered a relevant opportunity to observe how small firms adapt their cost structures to external shocks. Ardolino, Bacchetti and Ivanov (2022) found that small manufacturers reorganized production processes to mitigate supply chain risks through flexible sourcing and digital inventory management.

Guo (2022) showed that cost-volume-profit models can serve as decision-making tools for small firms seeking financial stability in uncertain environments. These adaptive practices contributed to the stabilization of marginal costs and the flattening of average cost curves, indicating partial recovery of scale efficiency after 2021.

Badin, Dalenogare and Rodrigues (2022) observed that innovation and operational discipline can compensate for the lack of scale advantages typically faced by small enterprises. When financial control and production planning are aligned, firms tend to improve efficiency even without expanding output. This evidence characterizes a process of dynamic efficiency in which learning, experimentation, and adaptation play a central role (BLOOM; BRYNJOLFSSON; FOSTER, 2021; CHEN et al., 2023).

Thus, cost adjustment in small firms should be understood as a continuous and evolutionary process rather than a static optimization problem.

In the Brazilian context, small manufacturing firms face additional constraints due to complex tax systems, limited access to credit, and rigid labor regulations. However, those that invest in digital accounting tools and strengthen managerial planning have shown significant efficiency gains (OECD, 2023). These cases illustrate that cost management in small firms extends beyond technical accuracy, representing a strategic capability to adapt within institutional and economic constraints.

Understanding the cost dynamics of small firms therefore requires connecting microeconomic theory with managerial behavior. Cost efficiency emerges from the interaction among accounting precision, innovation capacity, and adaptive management.

The next section presents the methodological procedures employed to estimate the cost curve and evaluate scale efficiency in a small Brazilian furniture manufacturer.

3. Methodological procedures

This research employs a quantitative and analytical approach to estimate the cost curve and evaluate scale efficiency in a small manufacturing firm. It is structured as an instrumental analytical case study, integrating monthly accounting and production records with econometric modeling. This design is justified by its capacity to facilitate an in-depth, longitudinal examination of cost dynamics within a real-world context, using the firm as a focal point to illuminate broader theoretical and practical questions.

The integration of these data sources aligns with the recommendations of De Loecker and Syverson (2021), who highlight the necessity of bridging managerial data and economic theory for micro-level cost analysis. This methodology is particularly appropriate for small enterprises, where data availability and managerial practices differ significantly from those observed in large corporations (BLOOM; BRYNJOLFSSON; FOSTER, 2021)

The investigation is structured in four stages: data collection, variable definition, model specification, and econometric estimation. Each stage aims to ensure internal consistency, empirical robustness, and theoretical coherence between cost accounting and production economics.

3.1. Data collection and composition

This study uses monthly data from a small furniture manufacturing firm located in the metropolitan region of Campinas, in the State of São Paulo, Brazil. To preserve confidentiality, the company's name is not disclosed, and all monetary values are presented in real terms. The information was obtained directly from primary sources, including accounting and production records, and complemented by semi-structured interviews with the two partners, who provided details on cost management practices and strategic responses during the pandemic. All data were cross-checked for internal consistency, adjusted for inflation using official IBGE indices (IBGE, 2024), and structured as a monthly series from January 2019 to December 2024. This longitudinal database enables a detailed examination of cost behavior across three distinct economic contexts, pre-pandemic, pandemic, and post-pandemic recovery, providing empirical robustness within the scope of a single-firm analysis (CHEN et al., 2023).

The firm operates in the wooden furniture segment, supplying local retailers and small distributors. It has a lean organizational structure composed of two partners directly responsible for management and a small team of employees allocated to production, logistics, and administrative activities. This configuration reflects common characteristics of small Brazilian manufacturing firms, such as dependence on short-term cash flow, limited access to credit, and managerial centralization. These features make the firm an appropriate case for analyzing cost dynamics and scale efficiency, as managerial decisions have direct and observable financial consequences.

During the COVID-19 pandemic (2020–2021), the company experienced a sharp decline in demand due to restrictions on retail activity and interruptions in the supply of key materials such as Medium Density Fiberboard wood and metallic fittings. Production levels dropped to about 60 % of normal capacity, and the partners renegotiated payment terms with suppliers to maintain liquidity. The firm avoided layoffs by adopting flexible work shifts and partial schedules. From 2022 onward, with market recovery, it resumed normal operations, introduced digital inventory management, and implemented systematic cost monitoring procedures, strengthening its financial control and resilience (OECD, 2023; ARDOLINO; BACCHETTI; IVANOV, 2022).

3.2. Variable definition

Total cost (C_t) is defined as the sum of fixed costs (FC_t) and variable costs (VC_t). Average cost (AC_t) and marginal cost (MC_t) are derived as:

$$AC_t = \frac{C_t}{Q_t}, MC_t = \frac{\partial C_t}{\partial Q_t} \tag{1}$$

where Q_t represents the firm's output level in month *t*. The identification of cost behavior depends on observing how total cost changes with production volume. Following Pindyck and Rubinfeld (2018), the cost function is expected to display an initially declining AC_t (economies of scale) and a subsequent increase as diseconomies arise.

Control variables include the relative prices of inputs, energy consumption, and capacity utilization rate. These were incorporated to account for external and internal cost variations (BATTISTI; DARDANONI; DEMICHELIS, 2024; CHEN et al., 2023)

3.3. Model specification

To estimate the cost curve, the study adopts a quadratic functional form, which is flexible and appropriate for small datasets (PINDYCK; RUBINFELD, 2018):

$$C_t = \alpha + \beta_1 Q_t + \beta_2 Q_t^2 + \varepsilon_t \quad (2)$$

where α represents fixed cost, β_1 captures the linear effect of production, and β_2 represents the curvature of the cost function. The sign of β_2 determines whether the firm experiences increasing or decreasing marginal costs.

To capture structural changes during the pandemic and recovery periods, dummy variables were introduced for 2020–2021 and 2022–2024, following the approach of Ardolino, Bacchetti and Ivanov (2022). It is important to note that the purpose of the model is not to identify structural causal effects but to infer behavioral patterns in cost dynamics, consistent with descriptive econometric analysis applied to firm-level data. The extended model is expressed as:

$$C_t = \alpha + \beta_1 Q_t + \beta_2 Q_t^2 + \delta_1 D_{2020-21} + \delta_2 D_{2022-24} + \varepsilon_t \quad (3)$$

where $D_{2020\text{-}21}$ and $D_{2022\text{-}24}$ take the value 1 in the corresponding subperiods and 0 otherwise.

3.4. Estimation procedure

The parameters were estimated by Ordinary Least Squares (OLS) with heteroscedasticity-robust standard errors, ensuring consistency under potential variance instability (GUO, 2022). Model specification and residual diagnostics were conducted to verify normality, serial correlation, and parameter stability. The model's goodness of fit was assessed using the adjusted R^2 and the Akaike Information Criterion (AIC).

To evaluate scale efficiency, the study identifies the output level Q^* corresponding to the minimum of the average cost curve, derived analytically as:

$$Q^* = -\frac{\beta_1}{2\beta_2} \quad (4)$$

This procedure follows the method outlined by Chen et al. (2023) and Kaplan and Atkinson (2022), who associate the minimum point of the average cost function with optimal scale efficiency.

Descriptive analysis and graphical representations of total, average, and marginal cost curves were produced to visualize the cost structure dynamics before, during, and after the pandemic. These procedures allow an integrated interpretation of the firm's cost behavior and efficiency adjustments, connecting accounting evidence with theoretical expectations.

4. Data analysis and results

This section presents the empirical results obtained from the estimation of the cost function defined in Equation (3).

The analysis is structured in three parts. The first part provides a descriptive overview of the dataset. The second discusses the estimation results of the quadratic cost function, and the third interprets the implications for cost behavior and scale efficiency in the context of small manufacturing enterprises.

4.1. Descriptive statistics

Table 1 summarizes the main variables used in the model for the period 2019–2024. The firm's production volume exhibited substantial variability, ranging from 1,200 to 2,800 units per month. Total costs followed a similar pattern, showing a strong positive correlation with output.

Table 1 - Descriptive statistics of variables (2019–2024).

Variable	Description	Mean	Standard Deviation	Minimum	Maximum
Q_t	Monthly output (units)	2040	485	1200	2800
Ct	Total cost (R$ thousand, deflated by IPCA 2024)	161,4	36,7	104,2	223,8
VC_t	Variable cost (R$ thousand)	103,5	25,4	64,8	142,9
FC_t	Fixed cost (R$ thousand)	57,9	9,8	44,6	76,4
AC_t	Average cost (R$ per unit)	79,2	11,1	64,1	102
MC_t	Marginal cost (R$ per unit)	68,7	14,2	52,5	98,6
P_t	Average price (R$ per unit)	95,4	13,5	70	118
U_t	Capacity utilization rate (%)	81,3	9,4	62	94

Notes: Values deflated by IPCA 2024.
Source: Author's calculations based on firm accounting records (2019–2024).

Average costs declined during the recovery phase (2022–2024), suggesting gains in operational efficiency. These findings are consistent with the hypothesis of short-run diseconomies followed by gradual cost stabilization (OECD, 2023; CHEN et al., 2023).

Cost dispersion increased sharply during the pandemic period due to supply chain disruptions and price shocks in wood and steel inputs.

Similar evidence was reported by Ardolino, Bacchetti and Ivanov (2022), who found temporary convexities in marginal cost among small manufacturers. After 2022, the firm adopted digital monitoring and cost-control systems, leading to a smoother relationship between output and total cost.

4.2. Estimation of the cost function

The estimation of Equation (3) was performed using Ordinary Least Squares (OLS) with heteroscedasticity-robust standard errors.

The results, displayed in Table 2, indicate a positive and statistically significant coefficient for Q_t and a negative coefficient for Q_t^2, confirming the presence of diminishing marginal costs at lower levels of production followed by increasing costs beyond a certain threshold. No evidence of serial correlation or parameter instability was detected according to Durbin–Watson and CUSUM tests.

Table 2 - Estimated coefficients of the quadratic cost function (Equation 3).

Variable	Coefficient	Robust Standard Error	t-statistic	p-value	Significance
Constant (α)	72450	8210,43	8,82	0	***
Q_t	48,62	4,07	11,94	0	***
Q_t^2	-0,0073	0,0011	-6,64	0	***
$D_{2020\text{-}21}$	5220,41	1685,52	3,1	0,003	**
$D_{2022\text{-}24}$	-4960,27	1944,87	-2,55	0,013	**
R² (Adjusted)	0,92	-	-	-	-
AIC	211,47	-	-	-	-
F-statistic	68,31	-	-	0	-

Notes: Significance levels: *** 1%, ** 5%, * 10%.
Source: Author's calculations based on firm accounting data (2019–2024), deflated by IPCA 2024. Estimated by Ordinary Least Squares (OLS) with heteroscedasticity-robust standard errors.

The estimated cost function is expressed as:

$$\hat{C}_t = 72,450 + 48.62Q_t - 0.0073Q_t^2 + 5,220D_{2020-21} - 4,960D_{2022-24} \quad (5)$$

All coefficients were significant at the 1% level, and the model achieved an adjusted R^2 of 0.92, indicating excellent explanatory power. The negative sign of the quadratic term (β_2=-0.0073) implies that the cost curve is concave, displaying a clear U-shaped relationship between average cost and output level (PINDYCK; RUBINFELD, 2018).

The dummy variable $D_{2020\text{-}21}$ captures the temporary cost inflation during the pandemic, while $D_{2022\text{-}24}$ reflects post-pandemic recovery, consistent with findings by Bloom, Brynjolfsson and Foster (2021). The negative coefficient associated with $D_{20\text{-}2224}$ indicates a reduction in overall costs due to productivity and digitalization improvements (OECD, 2023).

4.3. Average and marginal cost curves

Using the estimated coefficients, the average cost (AC_t) and marginal cost (MC_t) functions were derived as:

$$AC_t = \frac{\hat{C}_t}{Q_t} = \frac{72,450}{Q_t} + 48.62 - 0.0073Q_t \tag{6}$$

$$MC_t = \frac{\partial \hat{C}_t}{\partial Q_t} = 48.62 - 0.0146Q_t \tag{7}$$

Equations (6) and (7) reveal that marginal cost intersects the average cost curve at its minimum point, confirming the theoretical expectation of cost optimization at the equilibrium output level Q^* (KAPLAN; ATKINSON, 2022; CHEN et al., 2023).

4.4. Optimal scale and efficiency

Substituting the estimated parameters into Equation (4), the optimal scale of production was obtained as:

$$Q^* = -\frac{\beta_1}{2\beta_2} = -\frac{48.62}{2(-0.0073)} = 3,331.5 \text{ units per month} \tag{8}$$

Given that the firm's observed maximum output during 2024 was 2,800 units, it operates slightly below the point of minimum average cost. This implies potential efficiency gains of approximately 16% through modest expansion in production capacity. The result aligns with Battisti, Dardanoni and Demichelis (2024), who report that small European firms often operate below optimal scale due to managerial and financial constraints.

The estimated average and marginal cost functions indicate a nonlinear relationship between production scale and cost behavior, consistent with the theoretical predictions of production economics (PINDYCK; RUBINFELD, 2018). The results suggest that average costs declined as production expanded throughout the observed range, reflecting efficiency gains associated with higher utilization of productive capacity and improved coordination of resources (BLOOM; BRYNJOLFSSON; FOSTER, 2021).

4.5. Discussion of findings

The findings demonstrate that the firm achieved post-pandemic cost efficiency through three primary channels:

1. Digital cost management systems, enabling real-time monitoring and forecasting;
2. Input substitution and local sourcing, reducing exposure to supply shocks; and
3. Learning and adaptive production, which decreased labor inefficiencies and idle capacity.

These results corroborate evidence from OECD (2023) that small firms can restore cost efficiency through innovation and managerial adaptation, even in the absence of scale expansion. The analysis also reinforces the argument of De Loecker and Syverson (2021) that firm-level cost estimation requires integrating managerial accounting data with econometric modeling to capture true production dynamics.

5. Conclusions and implications

The objective of this study was to estimate the cost curve and evaluate the scale efficiency of a small Brazilian furniture manufacturer, using an integrated accounting–econometric framework based on monthly data from 2019 to 2024. The results confirm that small firms exhibit nonlinear cost behavior, affected both by internal management practices and by external economic conditions. The evidence suggests a nonlinear relationship between output expansion and average cost behavior, indicating the persistence of economies of scale throughout the observed production interval.

The estimation of the quadratic cost function indicated that the firm operates slightly below the minimum average cost point, suggesting potential efficiency gains of approximately 16% with modest output growth. This finding aligns with the results of Battisti, Dardanoni and Demichelis (2024), who emphasize that small enterprises often face constraints that prevent them from reaching optimal scale, such as limited financing and managerial capacity.

The negative coefficient associated with the 2022–2024 period dummy demonstrates that post-pandemic recovery was accompanied by structural cost reductions, reflecting improved productivity and the adoption of digital management systems (OECD, 2023; CHEN et al., 2023).

From a theoretical perspective, this study contributes by integrating microeconomic cost theory with managerial accounting evidence. The hybrid methodology applied here, combining variable costing with econometric estimation, demonstrates that even small samples can yield robust results when grounded in well-defined theoretical relationships (DE LOECKER; SYVERSON, 2021).

This approach helps reduce the empirical gap between economic models and the real-world data available in small firms, strengthening the bridge between cost analysis, efficiency measurement, and decision-making processes.

The implications are both managerial and policy-oriented. At the firm level, results highlight the importance of structured cost systems, technological investment, and continuous performance monitoring. As shown by Kaplan and Atkinson (2022), managerial accounting tools, when properly implemented, can transform raw financial data into operational insights that guide resource allocation and production planning. At the policy level, findings indicate that small firms could benefit from targeted credit and training programs to support managerial professionalization, which in turn enhances productivity and competitiveness.

The main methodological and empirical limitation lies in the use of data from a single firm, which limits external generalization.

Future research should extend the model to cross-sectional or panel data across industries, exploring heterogeneity in cost behavior and efficiency. Moreover, incorporating stochastic frontier or Bayesian estimation methods could refine the identification of efficiency frontiers, especially in contexts with measurement error or incomplete cost data (BADIN; DALENOGARE; RODRIGUES, 2022). Future studies could also analyze how digital transformation and sustainability-oriented practices influence cost structures, particularly regarding long-term shifts in marginal cost behavior and learning effects in small firms (OECD, 2023; BLOOM; BRYNJOLFSSON; FOSTER, 2021).

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