# THE LONG-RUN AVERAGE COST CURVE: EVIDENCE FROM THE BOTTLED WATER INDUSTRY

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***ABSTRACT***
*This paper examines the shape of the long-run average cost (LRAC) curve, a central concept in production economics and strategic management. While traditional neoclassical theory suggests a U-shaped curve, with costs declining and then rising due to diseconomies of scale, a significant body of empirical research points toward an L-shaped curve, where costs decline to the minimum efficient scale (MES) and then stabilise. Drawing on both theoretical and empirical perspectives, this paper applies a case study of a bottled water manufacturer in North Macedonia. Using production and cost data collected over a ten-year period, the study tests whether the LRAC follows the U-shaped or L-shaped pattern. The results show that after a phase of declining costs, the firm reached a zone of constant returns to scale, supporting the L-shaped hypothesis. The findings contribute to the debate on cost curve theory and provide managerial implications for capacity planning and efficiency.*

***Keywords:*** *Long-run average cost curve, Economies of scale, Bottled water industry, Cost efficiency, Case study*

***JEL classification:*** *M41, D24, L67*

## 1. INTRODUCTION

In economic and business practice, firms continually face the challenge of balancing output expansion and cost efficiency. As a result, the behaviour of average costs has become a central issue in both theory and management. During the early decades of the twentieth century, theoretical constructions established the average cost curve as one of the most frequently used instruments in microeconomic analysis and an indispensable element of the theory of the firm. However, precisely because of its ubiquity, the cost curve has often been applied inconsistently. As a result, interpretations of cost behaviour have often diverged between theoretical models and real-world business practice.

The average total cost (ATC) [1] represents the total cost per unit of output, calculated by dividing total production costs by the quantity produced, and serves as a key indicator for optimal scale and pricing. It provides a measure of efficiency at different levels of output and serves as a key indicator in determining optimal production scale and pricing strategies. In economic theory, the short run refers to a period when some production factors remain fixed, while in the long run, all inputs can be adjusted. This distinction depends not on time itself but on a firm's ability to modify resources and expand capacity as conditions change (Paunović, 2021). In practical terms, this distinction reminds us that short-run decisions are constrained by existing resources, whereas long-run efficiency depends on strategic investment choices.

[1] In this paper, the term "average total cost (ATC)" refers to short-run conditions where both fixed and variable costs are included. In the long run, all inputs are variable; hence the term "average cost" is used instead, as the "total" distinction becomes redundant. Both terms denote the average cost per unit of output.

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In the short run, the ATC curve in manufacturing companies is almost always presented as U-shaped. This shape suggests that short-run ATC first declines due to the fall in average fixed costs; then, as output increases further, costs stabilise and eventually rise (Larson, 1991). The "U" shape is thus explained by the notion that fixed costs within the production process cause ATC to be high at low output levels, while, on the other hand, there exist certain inputs that cannot be increased indefinitely, at least in the short run. When output is high, the shortage of these inputs constrains the efficiency with which they can contribute to increased production.
This naturally raises a question that has shaped decades of debate: What is the true form of the cost curve in the long run, once all inputs become variable? The literature provides two broad perspectives:

- Traditional perspective. Rooted in neoclassical economics, this view holds that the long-run average cost (LRAC) curve is also U-shaped, much like the short-run curve. This position is typically associated with Alfred Marshall, who explained increasing and diminishing returns using the concept of the representative firm (Marshall, 1920; Keppler & Lallement, 2006). As production expands, unit costs fall due to economies of scale; eventually, economies are exhausted, diseconomies arise, and unit costs increase.
- Empirical perspective. Most empirical studies indicate that the LRAC curve is L-shaped rather than U-shaped. Average costs decline until the minimum efficient scale (MES) is reached and then remain constant, or decline slightly further. According to this perspective, decreasing returns to scale are rarely observed in practice.

This paper addresses the question of LRAC shape through a combination of theory and empirical evidence. After reviewing the key literature, the paper applies a case study of a bottled water producer in North Macedonia, using company data to test whether the LRAC follows the U-shape or L-shape.

## 2. LITERATURE REVIEW

The precise shape of the LRAC curve has been the subject of economic debate for more than a century. This is understandable given its significance for strategic managerial decisions. While the LRAC has little operational role in day-to-day production management, it is highly relevant in determining the optimal size of production capacity. The distinction lies in the right-hand side of the curve: in the U-shape, costs eventually rise, while in the L-shape, they remain flat or even decline slightly. Given their distinct characteristics, the two shapes lead to fundamentally different managerial insights regarding capacity planning and efficiency improvement. While theory has often assumed a U-shape, empirical evidence increasingly suggests an L-shape. This section reviews the key contributions. Together, these contrasting perspectives underscore how the long-run cost concept has evolved from a theoretical construct into an empirically testable relationship.

### 2.1 The U-shaped LRAC

The U-shaped LRAC curve is strongly associated with neoclassical economics. It has been used to illustrate economies and diseconomies of scale [2] (Marshall, 1920; Scherer and Ross,

[2] The term "economies (and diseconomies) of scale" is used throughout this paper in accordance with standard microeconomic theory, where "scale" refers to changes in output level and associated cost behaviour. In contrast, some authors such as Chambers (1988), Debertin (1986), and Paunović (2021) distinguish between the two concepts, associating "economies of scale" with the technical properties of the production function and "economies of size" with long-run cost behaviour. Others, including Gravel and Rees (2004), Mauris and Thomas

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1990). As output expands, average costs decline due to economies of scale; however, beyond a certain point, diseconomies emerge, primarily linked to managerial inefficiencies, leading to rising costs (Coase, 1937; Canback, 2002).

Marshall introduced the concept of the representative firm, arguing that firms initially benefit from internal and external economies of scale but eventually face diminishing returns (Marshall, 1920; Keppler and Lallement, 2006). Later, Pigou (1927) elaborated the idea of the equilibrium firm, which reaches an optimal size where further expansion no longer reduces costs. Together, these contributions shaped the traditional U-shaped view of LRAC.

According to select modern literature, the traditional U-shaped LRAC curve remains a valid theoretical framework under specific conditions, though its empirical relevance is limited. Keat, Young, and Erfle describe the LRAC curve as typically U-shaped, reflecting economies of scale at lower output levels and diseconomies of scale at higher levels, and emphasise that the LRAC reaches its lowest point at the MES, beyond which average costs begin to rise (Keat *et al.*, 2017). Pindyck and Rubinfeld (2018) present the U-shaped LRAC in their foundational economic models, highlighting that average costs may eventually rise due to managerial diseconomies and coordination inefficiencies at higher output levels. Similarly, Hubbard,

O'Brien, and Rafferty (2022) acknowledge that the LRAC can be U-shaped in industries where operational complexity and logistical constraints increase with scale. Though empirical studies increasingly suggest flat or L-shaped cost structures, these authors defend the pedagogical and analytical utility of the U-shaped curve in understanding firm cost dynamics, particularly in sectors prone to scale inefficiencies.

**2.2 The L-shaped LRAC**

Empirical studies increasingly challenge the U-shape. Viner (1931) argued that in the absence of an "absolutely fixed factor" such as land, LRAC tends to flatten after the MES. Implicitly, this reasoning positioned constant average costs as the most common case in industries that did not depend on land or other absolutely fixed factors (Aslanbeigui and Naples, 1997). Scherer and Ross (1990) highlighted managerial and technological innovations that allow firms to sustain constant returns, while Williamson (1970) emphasised the importance of decentralised corporate structures in mitigating diseconomies of scale.

Wiles (1956) and Johnston (1960) found strong evidence that most industries exhibit an L-shaped LRAC, where costs fall and then stabilise. As Johnston observed, production may sometimes generate a U-shaped ATC curve in the short run, since firms attempting to expand output encounter capacity constraints. In the long run, however, enterprises can expand their capacities by constructing new facilities. If each facility operates efficiently, firms can grow as much as they wish without increasing average costs (Besanko *et al.*, 2017). Similarly, Jeganraj (2015) concluded that technological progress and sustainable practices enable firms to maintain costs at minimal levels, consistent with the L-shape hypothesis.

According to modern research, the traditional view of the LRAC curve as strictly U-shaped is increasingly challenged by empirical and theoretical findings. Ghani (2019) argues that the U-shaped LRAC is valid only under restrictive conditions and that actual cost behaviour

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(2002), Keat et al. (2017), Besanko et al. (2017), as well as classical and neoclassical economists such as Marshall (1920) and Viner (1931), generally use the term "economies of scale" to describe both phenomena. For the sake of consistency, this paper adopts only the term "of scale" when referring to cost behaviour relative to output volume.

frequently deviates from textbook models. Yinger (2023) supports this re-evaluation, highlighting a shift in economic thought toward recognizing the limitations of earlier assumptions and embracing models that better account for sustained economies of scale.

Lynham (2018) further illustrates that over a significant range of output, average production costs tend to remain stable—indicating a flatter LRAC curve. Taken together, these contributions suggest that in many process industries the LRAC remains flat over wide output ranges, reframing capacity planning as a problem of maintaining utilisation rather than avoiding inevitable diseconomies.

## 3. METHODOLOGY AND CASE STUDY

This section outlines the methodological approach and presents the case study evidence. The aim is to connect theoretical assumptions about the LRAC curve with the realities of business practice, illustrating how cost dynamics unfold in real production settings. By focusing on one company in the bottled water industry, it becomes possible to observe how production scale, cost dynamics, and efficiency interact in real operating conditions. The methodology combines descriptive cost analysis with a graphical interpretation of both short-run and LRAC curves, allowing a visual insight into how efficiency evolves with scale.

### 3.1 Research Design

The research paper applies the case study method to test whether the LRAC curve of a specific manufacturing firm follows a U-shape or an L-shape. Primary data were collected from company records through its Enterprise Resource Planning (ERP) system, covering the period from December 2011 to December 2021. The analysis is based on a real production cost data for a single product. For confidentiality reasons, the product name is omitted, while cost data are presented per unit in aggregated form.

### 3.2 Company Background

The case company, located in Skopje, North Macedonia, operates within the bottled water and soft drinks sector, a segment characterised by relatively stable demand and high capital intensity. Founded in 2000, it employs about 130 workers, with an annual turnover of approximately €10 million and total assets of €12 million.

### 3.3 Data and Variables

Data were collected from randomly selected production work orders over a ten-year period. The dataset covers production in 3 different scales. For each scale, two variables were measured:

- Q = quantity of output (in number of units)
- ATC = average total cost (€ per single unit)

Table 1 summarises the dataset used in the analysis.

*Table 1: Summary of production volumes and ATC*

| Scale 1 | | Scale 2 | | Scale 3 | |
|---|---|---|---|---|---|
| **Quantity** | **ATC** | **Quantity** | **ATC** | **Quantity** | **ATC** |
| 102 | 0,294 € | 9.864 | 0,159 € | 13.430 | 0,191 € |
| 738 | 0,194 € | 10.080 | 0,142 € | 15.430 | 0,180 € |
| 1.194 | 0,175 € | 10.326 | 0,137 € | 16.124 | 0,170 € |
| 2.520 | 0,172 € | 10.350 | 0,130 € | 18.996 | 0,135 € |

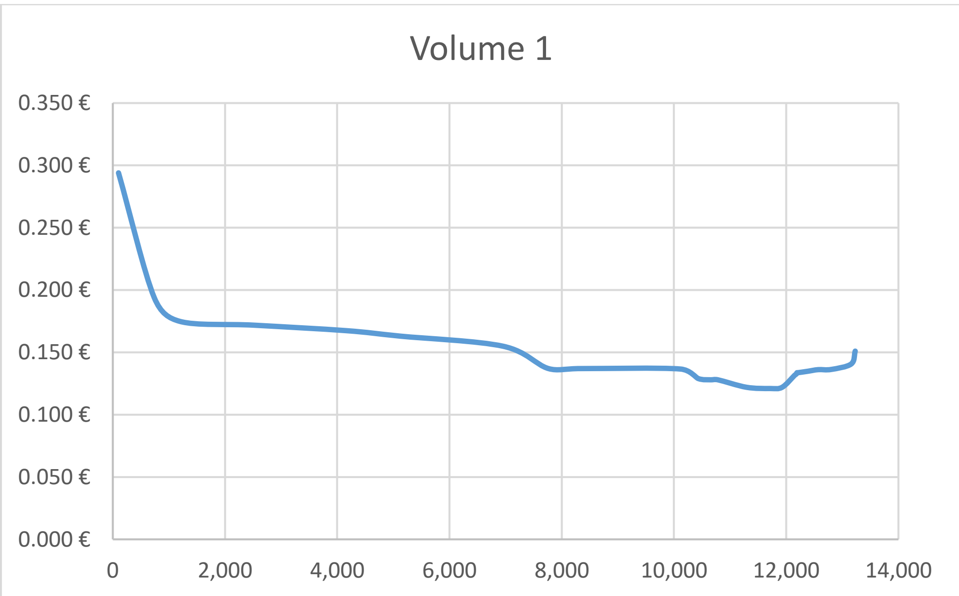
| | | | | | |
|---|---|---|---|---|---|
| 4.158 | 0,167 € | 10.446 | 0,129 € | 18.996 | 0,135 € |
| 5.118 | 0,163 € | 10.512 | 0,128 € | 21.032 | 0,132 € |
| 6.954 | 0,155 € | 10.644 | 0,128 € | 26.388 | 0,130 € |
| 7.764 | 0,137 € | 10.758 | 0,127 € | 26.724 | 0,126 € |
| 8.340 | 0,137 € | 11.148 | 0,125 € | 29.178 | 0,121 € |
| 10.116 | 0,137 € | 12.084 | 0,124 € | 29.220 | 0,118 € |
| 10.432 | 0,129 € | 12.318 | 0,124 € | 29.628 | 0,110 € |
| 10.656 | 0,128 € | 13.140 | 0,123 € | 33.486 | 0,109 € |
| 10.782 | 0,128 € | 13.578 | 0,122 € | 34.308 | 0,104 € |
| 11.292 | 0,122 € | 13.728 | 0,122 € | 35.010 | 0,103 € |
| 11.712 | 0,121 € | 14.412 | 0,119 € | 35.088 | 0,102 € |
| 11.928 | 0,122 € | 15.084 | 0,119 € | 40.062 | 0,101 € |
| 12.150 | 0,132 € | 15.504 | 0,115 € | 40.194 | 0,100 € |
| 12.180 | 0,133 € | 15.594 | 0,113 € | 43.008 | 0,100 € |
| 12.192 | 0,134 € | 16.386 | 0,112 € | 44.206 | 0,097 € |
| 12.210 | 0,134 € | 18.048 | 0,111 € | 44.256 | 0,097 € |
| 12.384 | 0,135 € | 19.542 | 0,111 € | 44.808 | 0,097 € |
| 12.570 | 0,136 € | 19.632 | 0,113 € | 50.376 | 0,096 € |
| 12.804 | 0,136 € | 20.064 | 0,120 € | 52.944 | 0,093 € |
| 13.158 | 0,141 € | 20.418 | 0,130 € | 53.112 | 0,092 € |
| 13.230 | 0,151 € | 20.790 | 0,133 € | 59.822 | 0,091 € |

*(Source: Author's calculations based on the company's ERP data)*

### 3.4 Case Study Findings

- Scale 1. The short-run ATC is U-shaped. Costs fall steeply at low output due to declining fixed costs, then stabilise, and finally rise when output exceeds ~12.000 units.

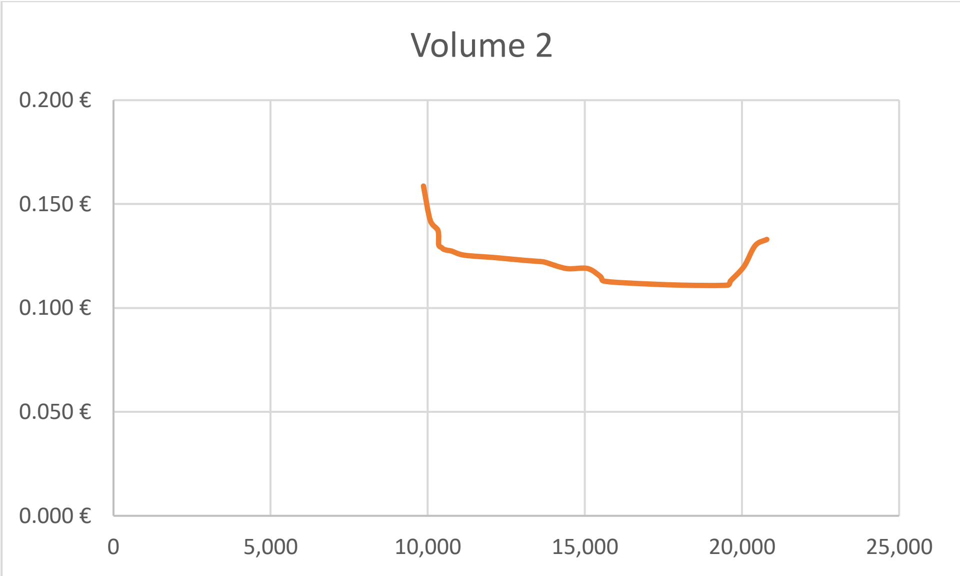
*Figure 1: Short-run ATC curve, Scale 1*




*(Source: Author's own calculations based on collected data)*

- Scale 2. The ATC again follows a U-shape. MES is reached at an output of ~18.000 units, while average costs rise beyond ~20.000 units, manifesting diseconomies of scale.

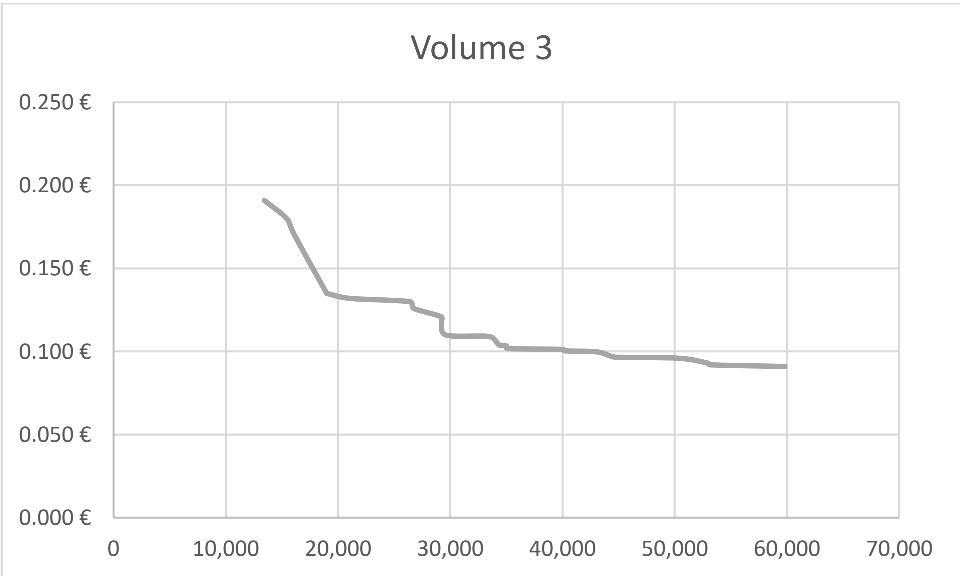
*Figure 2: Short-run ATC curve, Scale 2*




*(Source: Author's own calculations based on collected data)*

- Scale 3. The ATC is closer to L-shaped, with no evidence of rising costs at higher volumes. This demonstrates operations under constant returns to scale.

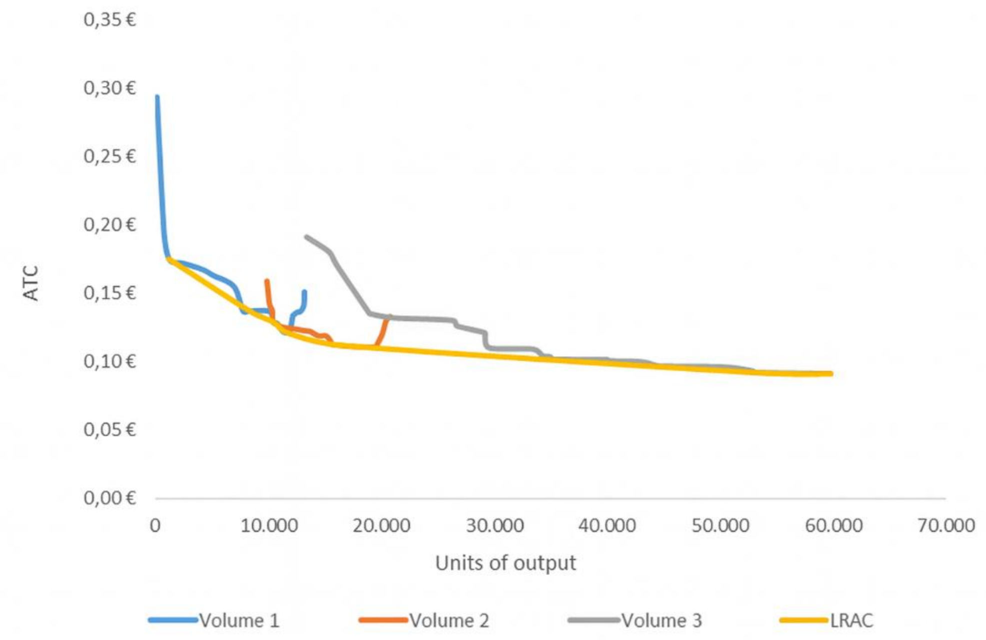
*Figure 3: Short-run ATC curve, Scale 3*




*(Source: Author's own calculations based on collected data)*

By integrating the three short-run ATCs, we can obtain the LRAC curve. It shows an initial phase of declining costs, followed by a long zone of constant returns to scale, with no evidence of rising costs at high output. As observed from the combined data, this integration highlights the transition from plant-level efficiency to long-run scale behaviour.

*Figure 4: LRAC curve*




*(Source: Author's own calculations based on collected data)*

**3.5 Statistical Considerations**

Although this study primarily relies on graphical analysis to examine the relationship between output and ATC, future research could strengthen the empirical validity of these findings through statistical testing. Regression analysis could be applied to measure the significance and stability of cost-output relationships across different production scales. However, given the limited sample size and focus on a single firm, this paper emphasises a qualitative interpretation of the data, which aligns with the exploratory character of the research.

## 4. RESULTS AND DISCUSSION

The case study supports the L-shaped LRAC. While small-scale capacities showed U-shaped short-run ATC, the LRAC curve stabilised at constant returns. This aligns with empirical findings by Wiles (1956), Johnston (1960), and Viner (1931), who emphasised that in most industries costs do not rise once MES is reached. Managerially, this means scale expansions can proceed without automatic cost penalties provided utilisation discipline is sustained.

The results challenge the neoclassical U-shaped view (Marshall, 1920; Pigou, 1927), but support the modern perspective that technology, organisation, and managerial innovations (Scherer and Ross, 1990; Williamson, 1970) mitigate diseconomies of scale.

From a managerial standpoint, the findings suggest that firms can expand operations without inevitable cost increases—so long as efficiency discipline and proactive capacity planning are maintained.

### 4.1 Generalizability and Industry Context

While the case study provides solid, company-level evidence on LRAC behaviour, its generalizability is necessarily limited. The bottled water industry exhibits several structural features that may shape cost dynamics in ways not fully representative of other manufacturing settings: (i) The industry relies heavily on fixed assets such as PET bottling lines, blow-moulding equipment, labelling, clean-in-place (CIP) systems and automatic packaging, which allow fixed costs to be spread over a larger output; (ii) Production is standardised and process-oriented, with relatively few product variations, so set-up and changeover costs although evident, are still lower than in plants producing many different products; (iii) Demand in regional markets is generally stable and predictable, which helps maintain high capacity utilisation; and (iv) The main costs come from packaging materials and energy, offering little flexibility to substitute inputs in the short run. In addition, company-specific factors such as access to technological know-how, maintenance practices, and the maturity of costing systems may further tilt observed average costs toward an L-shaped profile by constraining managerial diseconomies and supporting efficient scale. Consequently, the L-shaped LRAC identified here should be interpreted as context-dependent**:** comparable patterns are most likely in process industries with high fixed costs, standardised outputs, and sustained utilisation, whereas sectors with greater product heterogeneity, volatile demand, or complex coordination burdens may display different LRAC trajectories. These contextual differences reinforce the importance of analysing cost structures within their specific industrial settings rather than assuming uniform cost behaviour.

### 4.2 Limitations

This study has several limitations that should be acknowledged. First, the analysis is based on a single case study within the bottled water industry, and consequently, the cost behaviour observed may reflect the specific technological, organisational, and market characteristics of this firm rather than the entire sector. Second, the study relies primarily on historical production and cost data, which limits the ability to control for external factors such as changes in input prices or demand fluctuations. Third, graphical methods were used to interpret cost trends, without applying more advanced econometric techniques that could statistically confirm the shape of the LRAC curve.

## 5. CONCLUSION

This paper analysed the LRAC curve through theoretical and empirical perspectives. The study combined a literature-based discussion of cost curve behaviour with a case study from the bottled water industry, where production data from a single firm were used to construct short-run ATC curves and derive the LRAC curve.

Based on the evidence presented, three key conclusions emerge from this analysis, each reflecting a different dimension of the cost–scale relationship. First, while the U-shaped LRAC remains an important theoretical construct, it does not fully align with the empirical evidence obtained in this study. The observed cost pattern better corresponds to the L-shaped curve, characterised by initially declining and subsequently constant average costs. Second, the results support the view that firms can sustain efficiency at optimal scale without triggering diseconomies of scale, especially in industries with standardised production processes and stable demand conditions. Third, the case study demonstrates that industry-specific characteristics—such as capital intensity, process standardisation, and energy-dependent cost structures—can significantly shape the cost-output relationship, limiting the generalisability of results.

Future research should expand the analysis to a broader sample of firms and employ advanced econometric or artificial intelligence (AI) techniques to assess statistical significance and predict LRAC dynamics. Such approaches could deepen the empirical understanding of cost behaviour and, in practice, strengthen managerial decision-making in capacity planning and cost optimisation. Ultimately, the evidence supports treating LRAC in process industries as flat beyond MES, with managerial focus on sustaining utilisation and reliability rather than anticipating diseconomies by default.

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