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DEA-VRS ANALYSIS OF TECHNICAL EFFICIENCY IN LOCAL FURNITURE SMES

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Abstract This study addresses the limited empirical research on the technical efficiency of small and medium-sized furniture enterprises (SMEs) in Indonesia, particularly in Bireuen Regency, where the sector plays a vital role in regional economic development yet faces persistent challenges of capital constraints, skilled labor shortages, and volatile raw material supplies. The purpose of this research is to measure the level of technical efficiency of local furniture SMEs and to identify both internal and external determinants influencing performance. Using a census approach, data were collected from 287 active enterprises through surveys, interviews, and secondary sources. Technical efficiency was analyzed with Data Envelopment Analysis (DEA) under a Variable Returns to Scale (VRS) model, enabling the evaluation of multiple input-output relationships. The findings reveal that 56.6% of enterprises operate efficiently, while 43.4% remain inefficient due to excessive investment, overuse of raw materials, and suboptimal labor utilization. External factors such as access to financing, wood supply chain stability, workforce skills, and supportive government policies were found to significantly influence efficiency outcomes. The study concludes that improving access to microfinance, strengthening sustainable wood supply chains, enhancing labor training, and implementing targeted policy support are critical strategies to enhance the competitiveness and sustainability of local furniture SMEs.

Keywords:Technical Efficiency, DEA-VRS, Furniture SMEs, External Determinants

1. Introduction

The furniture industry is one of the manufacturing subsectors that significantly contributes to both regional and national economies. Demand for furniture continues to increase in line with population growth, housing development, urbanization, and lifestyle improvements. In addition, the expansion of the private sector and the development of public infrastructure are also key drivers behind the rising demand for furniture products (Zhang et al., 2021).

In Bireuen Regency, the wood-based furniture industry—more commonly known as the household furniture industry—has become one of the leading sectors in regional development. Furniture enterprises are spread across almost all districts, with particularly high concentrations in Kota Juang and Jeumpa. Interestingly, although Kota Juang has the largest number of enterprises, data show that the number of businesses has remained relatively stable over the past three years, indicating resilience and sustainability in this sector.

However, the furniture industry in Bireuen faces several fundamental challenges affecting its production performance. First, limited working capital or investment remains a major obstacle. Entrepreneurs generally only produce after receiving orders, forcing consumers to wait longer, which often drives them to purchase ready-made furniture from outside the region (Nugroho & Haryanto, 2022). Second, the shortage of skilled labor in the furniture sector reduces product competitiveness, compelling some business owners to hire workers from outside the region, thereby increasing labor costs (Yusuf et al., 2023).

Additionally, raw material availability has become increasingly critical. High-quality wood is harder to obtain due to the depletion of natural forest resources and stricter environmental protection regulations. This scarcity drives up raw material prices, which in turn reduces the profit margins of local furniture enterprises (Ali et al., 2021).

Technical efficiency is a decisive factor for business sustainability, considering the limited access to capital, fluctuating raw material prices, and uneven labor quality. Recent studies confirm that input efficiency directly affects productivity and profitability in manufacturing SMEs. For instance, Zhang et al. (2021) demonstrated that optimizing investment and labor inputs improved the competitiveness of small-scale furniture industries in China. Meanwhile, Nugroho and Haryanto (2022) in Indonesia confirmed that capital constraints and rising wood prices reduce profit margins among small business operators.

In the context of efficiency, it is important to assess how far production inputs—including investment, raw materials, and labor—are utilized optimally to maximize output. Technical efficiency is a key determinant of business sustainability, particularly amidst competition with furniture products from other regions or imports. Data Envelopment Analysis (DEA) has been widely applied in manufacturing research to evaluate relative efficiency among similar business units, as it can identify best practices and provide concrete recommendations for underperforming enterprises (Emrouznejad & Yang, 2018). Moreover, the Variable Returns to Scale (VRS) approach is considered suitable for analyzing small-scale businesses, which typically have not yet reached optimal operational scales (Ali et al., 2021).

Therefore, this research is important to analyze the extent of technical efficiency in the furniture industry of Bireuen Regency, particularly in terms of production input utilization. The findings are expected to serve as a basis for entrepreneurs, local governments, and other stakeholders in formulating strategies to enhance the competitiveness of local furniture industries—through capital support, workforce skills improvement, and sustainable raw material supply chain strengthening.

2. Literature Review

2.1 Technical Efficiency and Data Envelopment Analysis (DEA)

Technical efficiency refers to the ability of a production unit to maximize output with the limited resources available. A producer is said to be technically efficient if it is no longer possible to increase output without adding inputs, or conversely, if inputs cannot be reduced without lowering output (Coelli et al., 2005). In the context of small and medium-sized enterprises (SMEs), technical efficiency serves as an important indicator of competitiveness and business sustainability, especially in labor-intensive sectors such as the furniture industry.

Data Envelopment Analysis (DEA) is a non-parametric approach widely used to measure relative efficiency across Decision Making Units (DMUs). DEA enables the simultaneous comparison of multiple inputs and outputs, making it suitable for analyzing the furniture industry, which involves complex variables such as capital, raw materials, and labor (Emrouznejad & Yang, 2018). In this study, the Variable Returns to Scale (VRS) model is applied, as most furniture enterprises in Bireuen Regency operate below their optimal scale.

2.2 Applications of DEA in Furniture and Wood-Processing Industries

Several international studies have applied DEA to the furniture and wood-processing sectors. Zhang et al. (2021) found that SMEs in the Chinese furniture industry displayed considerable

efficiency variation, where capital constraints and supply chain management were the main barriers. Studies on small-scale wood-processing enterprises in Europe reported similar findings: many units faced inefficiencies due to excessive labor use and high raw material costs (Le Bel et al., 2023).

Moreover, recent research in Indonesia (Nugroho & Haryanto, 2022) highlighted that working capital constraints and fluctuations in wood prices significantly affect the technical efficiency of local furniture producers. Therefore, DEA is not only relevant for measuring efficiency but also useful for providing practical recommendations to minimize input waste.

2.3 Input Factors in the Furniture Industry

2.3.1 Capital or Investment

Working capital is the primary factor determining production capacity. Investments in modern machinery, production facilities, and working capital to ensure smooth raw material supply have proven to increase productivity (Ali et al., 2021). However, in many regions, including Bireuen Regency, access to formal financing remains limited, forcing furniture entrepreneurs to adopt a make-to-order production system, which negatively impacts efficiency.

2.3.2 Raw Materials

Wood is the main input in the furniture industry. A major challenge arises from the limited availability of high-quality hardwoods and rising raw material costs. Environmental protection regulations further restrict the supply of legal timber, pushing entrepreneurs to seek alternatives such as composites, MDF, or bamboo that can reduce costs while maintaining product quality (Yusuf et al., 2023). Global research on wood supply chains emphasizes that supply sustainability is a key determinant of efficiency in the furniture industry (Winkel et al., 2024).

2.3.3 Labor

Labor serves as an active production factor. Skill quality (craftsmanship) plays a decisive role in adding value to furniture products through design, carving, and finishing. However, many furniture SMEs face shortages of skilled labor, forcing them to recruit workers from outside the region at higher costs (Le & Nguyen, 2022). Skill training and design innovation are seen as effective solutions to improve labor efficiency.

2.4 Supply Chain and Sustainability

Recent studies indicate that supply chain integration significantly influences efficiency in the furniture industry. Institutional pressures, such as legal timber certification, also encourage companies to adopt more efficient and environmentally friendly practices (Tukamuhabwa et al., 2023). Furthermore, the COVID-19 pandemic has exposed the vulnerabilities of global furniture supply chains, making resilience strategies and digitalization increasingly relevant (Akyuz et al., 2024).

2.5 Sustainability and Environmental Efficiency

Efficiency measurement no longer focuses solely on technical and economic aspects but also incorporates environmental dimensions. Environmental-adjusted DEA approaches are widely used to assess efficiency by including emissions, wood waste, or energy use as undesirable outputs (Sueyoshi & Goto, 2020). In the furniture industry, integrating sustainability considerations is critical, as global markets increasingly demand environmentally friendly and certified products.

2.6 Conceptual Framework

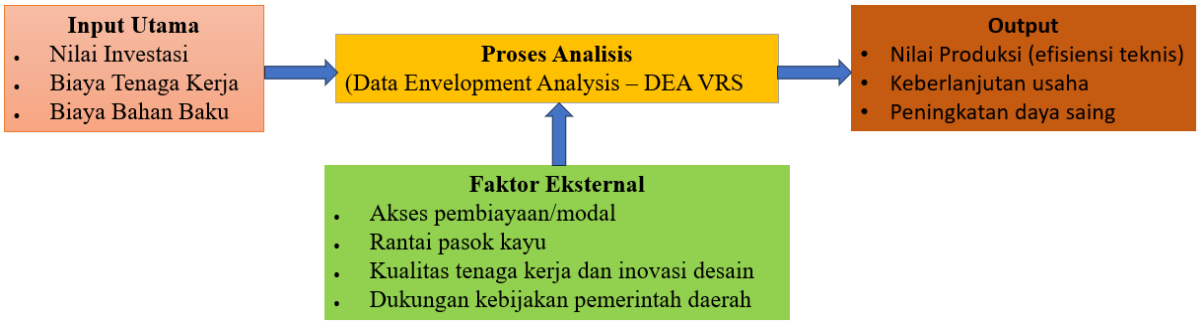

Figure 1.2 Conceptual Framework

This conceptual framework places technical efficiency as the core variable, with primary inputs as direct determinants, and external factors as additional explanatory elements influencing efficiency levels.

3. Method

3.1 Research Object and Location

The object of this study is the technical efficiency of production input utilization, which consists of investment value, labor costs, and raw material costs, against production output in the form of the total production value of furniture enterprises. The research location was determined in Bireuen Regency, Aceh Province, since this area represents one of the main furniture industry centers with a significant number of business units that have remained relatively stable in recent years.

3.2 Population and Sample

The study population comprises all registered furniture enterprises in Bireuen Regency under the Department of Industry. Based on the most recent data, there were 287 active enterprises. This study employed a census or total sampling technique, meaning the entire population was used as the research sample. Thus, the number of analyzed enterprises was 287. The use of a census method was intended to provide a more comprehensive picture and avoid bias due to sample limitations.

3.3 Data Collection Methods

Data were collected through two approaches: Secondary Data: Obtained from related institutions such as the Department of Industry of Bireuen Regency and the Central Statistics Agency (BPS). This included information on the number of enterprises, investment values, and furniture industry development trends (BPS, 2024). And Primary Data: Collected through structured questionnaires and interviews with owners or managers of furniture enterprises. This covered details on raw material costs, labor costs, production values, as well as additional insights regarding business challenges and strategies.

In addition, the study was complemented by literature reviews from journal articles, books, and research reports related to technical efficiency and the application of DEA in manufacturing and furniture industries.

3.4 Data Analysis Methods

3.4.1 Data Envelopment Analysis (DEA)

This study applied Data Envelopment Analysis (DEA), a non-parametric method that enables measurement of relative efficiency across decision-making units (DMUs), considering multiple inputs and outputs simultaneously (Emrouznejad & Yang, 2018).

DEA calculates efficiency as the weighted ratio of outputs to inputs. A DMU is efficient if the efficiency score = 1, while a score < 1 indicates relative inefficiency. One advantage of DEA is that it does not require the specification of a production function, making it suitable for analyzing furniture SMEs with diverse input-output characteristics.

3.4.2 Variable Returns to Scale (VRS) Approach

This study employed the Variable Returns to Scale (VRS) or BCC model, based on the assumption that furniture enterprises in Jeumpa have not yet reached optimal operational scales. With the VRS approach, the relationship between additional inputs and outputs is not necessarily proportional, allowing the model to capture both increasing returns to scale (IRS) and decreasing returns to scale (DRS).

Mathematically, the VRS DEA model can be expressed as:

Max $\pi = \sum r=1 s u r y r j \sum i=1 m v i x i j$ \text{Max } \pi = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}

Subject to:

$\sum r=1 s u r y r k - \sum i=1 m v i x i k \leq 0, \forall k$ \sum_{r=1}^{s} u_r y_{rk} - \sum_{i=1}^{m} v_i x_{ik} \leq 0, \quad \forall k $u r, v i \geq 0$ u_r, v_i \geq 0

Where:

- π \pi = efficiency score of DMU
- $x i j$ x_{ij} = input ii of DMU jj
- $y r j$ y_{rj} = output rr of DMU jj
- $u r, v i$ u_r, v_i = weights endogenously determined by the model

This approach allows the research to provide concrete recommendations regarding input reduction or output enhancement to achieve efficiency.

4. Result and Discussion

4.1 Efficiency Measurement Results Using DEA-VRS

Technical efficiency analysis was conducted using Data Envelopment Analysis (DEA) with the Variable Returns to Scale (VRS) input-oriented model. From 287 furniture enterprises, the results were as follows:

a. 162 enterprises (56.6%) operated efficiently (efficiency score = 1.00).

b. 125 enterprises (43.4%) were inefficient (efficiency score < 1.00).

These results indicate that although the majority of enterprises have optimized input use (investment, labor, raw materials), nearly half still experience resource inefficiencies.

4.3 Patterns of Input Inefficiency

Further analysis shows that inefficiency was mainly caused by:

a. Excessive Investment Costs, which were too high relative to the output produced.

b. Overuse of Raw Materials, not proportional to the production value generated.
c. Suboptimal Labor Utilization, where some enterprises employed more workers than necessary.

Case examples:

a. Enterprises owned by Fadli Muhammad, M. Yusuf Ismail, and Zamzami M. Yusuf had efficiency scores of 0.919. To reach efficiency, investment needed to be reduced by 8.11% and raw material use by 8.1%.
b. Syambudiman's enterprise, with a score of 0.869, required reducing the workforce from three to two workers, cutting investment by more than 20%, and decreasing raw material use by 13.1%.
c. Zakaria Hamzah's enterprise, with the lowest score (0.734), showed a need for up to 50% investment reduction and significant raw material efficiency.

4.4 Implications for the Conceptual Framework

The findings reinforce the study's conceptual framework, showing that output efficiency is determined not only by input management (investment, labor, raw materials) but also by external factors, such as:

a. Access to Capital: Efficient enterprises generally had better access to financing. Microfinance allowed them to invest in machinery, raw materials, and production expansion, ensuring smoother operations and faster responses to market demand.
b. Wood Supply Chain: Stable and sufficient wood availability was crucial. Smooth supply reduced waiting times and costs, while fluctuating prices significantly affected profit margins.
c. Labor Quality: Skilled workers improved efficiency and product quality. Experienced workers completed tasks faster and with fewer errors, boosting productivity.
d. Policy Support: Local government policies—such as tax incentives, training programs, and market access—played a critical role. Simplified licensing and reduced bureaucracy also facilitated enterprise operations.

These results align with studies by Zhang et al. (2021) in China and Ali et al. (2021) in small manufacturing sectors, which confirmed that furniture SMEs' efficiency is highly influenced by capital constraints, raw material price fluctuations, and labor skills.

Thus, strategies to improve efficiency in the furniture industry should focus on:

1. Strengthening access to microfinance.
2. Developing sustainable wood supply chains to stabilize raw material prices.
3. Enhancing skilled labor training to minimize production waste.
4. Expanding government support through tax incentives, equipment subsidies, and marketing facilitation.

Discussion

Technical Efficiency Levels of the Furniture Industry in Bireuen Regency

The research results show that 56.6% of enterprises were efficient (DEA score = 1.00), while 43.4% were inefficient (DEA score < 1.00). This indicates that although most entrepreneurs were able to optimize input use, nearly half still faced serious challenges in resource management.

This phenomenon is consistent with the theory of technical efficiency, which states that efficiency occurs when a business unit can produce maximum output with given inputs or use the minimum inputs required to produce the same output.

These findings are in line with studies by Zhang et al. (2021) in China and Le Bel et al. (2023) in Europe, which demonstrated that small-scale furniture industries show wide efficiency variations, with inefficiencies largely caused by capital and raw material waste.

Causes of Inefficiency: Input Perspective

DEA-VRS analysis identified three major sources of inefficiency:

1. Excessive Investment Value, Many entrepreneurs allocated investments disproportionate to their production output. For example, some small enterprises invested heavily in equipment, but production capacity remained low. This finding is consistent with Ali et al. (2021), who emphasized that limited capital management often prevents SMEs from utilizing investments optimally.
2. High Raw Material Costs, Fluctuating wood prices and limited local supply caused over-costing in raw materials. This supports Winkel et al. (2024), who highlighted the crucial role of global wood supply chains in determining furniture industry efficiency.
3. Suboptimal Labor Utilization, Some enterprises employed more workers than required. This reflects low labor efficiency, aligning with Le & Nguyen (2022), who stressed the importance of craftsmanship in improving furniture production efficiency.

The Role of External Factors in Efficiency

In addition to technical inputs, the study found that efficiency was also influenced by external factors, including:

a. Access to Capital: Efficient enterprises generally relied on microfinance or cooperatives, while inefficient ones depended more on personal capital.
b. Wood Supply Chain: Enterprises with stable wood suppliers were more efficient than those purchasing from fluctuating open markets.
c. Labor Quality: Skilled workers enabled high-value products to be produced with fewer raw materials.
d. Policy Support: Local government programs in training and equipment assistance significantly supported technical efficiency.

These results are consistent with Tukamuhabwa et al. (2023), who found that supply chain integration and institutional pressures (e.g., legal timber certification) significantly impact the performance of the furniture industry.

Theoretical Implications

This research enriches the literature on furniture SMEs' technical efficiency using the DEA-VRS approach. Theoretically, the findings confirm that:

1. Technical efficiency in furniture SMEs is influenced not only by input-output combinations but also by external factors (capital access, supply chains, and policy support).
2. The DEA-VRS model is more appropriate for SMEs, as it captures variations in production scale (increasing/decreasing returns to scale).
3. Efficiency is not merely an internal company issue but also a systemic phenomenon involving supply chain ecosystems and regional policy frameworks.

Practical and Policy Implications

Based on the results, several practical recommendations can be proposed:

1. Enhancing Access to Capital

   Local governments should facilitate low-interest microfinance schemes to allow entrepreneurs to align investments with production capacity.

2. Strengthening Sustainable Wood Supply Chains

   Collaboration among governments, cooperatives, and local suppliers is needed to ensure affordable and legal wood supply.

3. Labor Training and Certification

   Skill-upgrading programs should be expanded to enable local workers to produce high-quality furniture with efficient raw material use.

4. Technology and Innovation Interventions

   The adoption of simple but productive machinery can help reduce input waste and improve output quality.

5. Government Policy Support

   Through equipment subsidies, marketing facilitation, and export promotion of local furniture products, competitiveness in Jeumpa's furniture industry can be further enhanced.

Thus, the technical efficiency of furniture enterprises in Jeumpa depends not only on internal management but also on external support, including financing, supply chains, labor development, and government policies.

5. Conclusions

Based on the analysis using the Variable Returns to Scale (VRS) DEA model of 287 furniture enterprises in Bireuen Regency, several conclusions can be drawn:

1. Technical Efficiency Levels. Out of 287 enterprises, 162 (56.6%) operated efficiently (DEA score = 1.00), while 125 (43.4%) were inefficient (DEA score < 1.00). This indicates that although most entrepreneurs optimized inputs, nearly half of the enterprises still faced inefficiencies.
2. Causes of Inefficiency. Inefficiency was mainly due to disproportionate input utilization, including: Investment values exceeding production capacity, Excessive raw material costs caused by limited access to high-quality wood and Suboptimal labor utilization, where the number of workers was disproportionate to the output produced.
3. Role of External Factors. Technical efficiency was influenced not only by input management but also by external factors such as access to financing, wood supply chains, labor skills, and local government policy support.
4. Theoretical and Practical Implications. This study strengthens the literature on furniture SME efficiency in developing countries by showing that the DEA-VRS model is relevant for assessing variations in scale. Practically, the study provides actionable recommendations for entrepreneurs, local governments, and stakeholders to enhance the competitiveness of the local furniture industry.

5.2.Suggestions

1. For Furniture Entrepreneurs**:**
   a. Control production costs, especially investment and raw materials, to align with output.
   b. Improve labor efficiency through skills training and product design innovation.
   c. Utilize simple yet efficient production technologies to reduce input waste.
2. For Local Government:
   a. Provide easier access to capital through low-interest microcredit schemes.
   b. Develop sustainable wood supply chain programs to ensure legal and affordable raw material availability.
   c. Conduct regular training programs for local labor to improve skills.
   d. Support the marketing of local furniture products through exhibitions, SME digitalization, and export promotion.
3. For Academics and Future Researchers:
   a. Expand research to other districts in Bireuen Regency or other areas in Aceh to obtain comparative insights.
   b. Incorporate environmental efficiency (e.g., emissions, wood waste, energy use) into DEA analysis for a more comprehensive evaluation.

Consider using hybrid DEA methods (such as DEA-Malmquist or DEA-Tobit regression) to examine long-term productivity dynamics and determinants of inefficiency.

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