CHAPTER 1

INTRODUCTION

1.1 Research Background

In the current era of global uncertainty, manufacturing and agroindustrial sectors face mounting pressure to become more adaptive in safeguarding food security and supply chain stability. Sugar occupies a strategically significant position within Indonesia's food economy, serving simultaneously as an essential raw material for the food and beverage industry and as a basic commodity for the general population (Tritisari, 2023). Nevertheless, constraints in sugarcane supply as the primary input, compounded by the relatively low productivity of domestic sugar mills, have left Indonesia chronically dependent on imports to satisfy national demand (Silalahi, 2024). This condition underscores the urgency of improving efficiency and productivity across the sugar industry as a prerequisite for strengthening national food security amid an increasingly volatile global landscape.

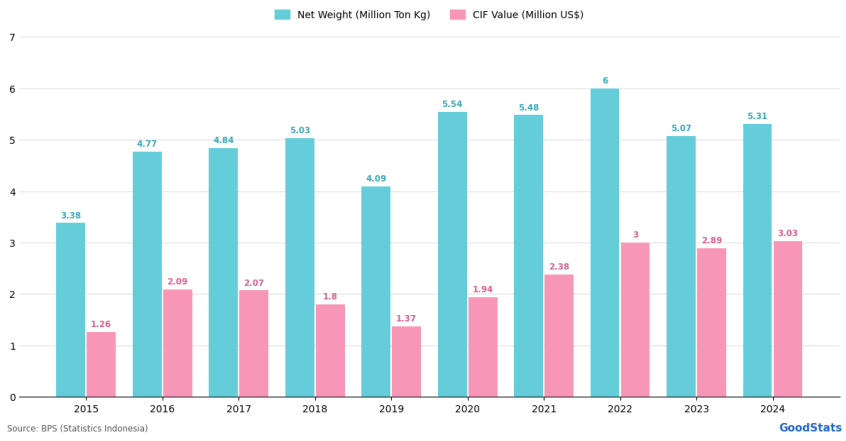

Figure 1. 1 Sugar Import History 2015–2024

Source: Data from the Last 10 Years of Sugar Import Reports by BPS (2025)

Historical import data presented in Figure 1.1 reveal a considerably pronounced upward trend in Indonesia's sugar imports over the past decade. Import volumes rose from approximately 3.36 million tons in 2015 to more than 6 million tons in 2022, before declining modestly to 5.06 million tons in 2023 (BPS, 2025). This sustained import escalation signals that domestic production has remained incapable of meeting national sugar demand, primarily due to persistent inefficiencies and productivity constraints within the industry (Silalahi, 2024). Such a finding is consistent with Yusuf et al. (2020), who established that the productive capacity of domestic sugar mills remains suboptimal owing to technical operational bottlenecks.

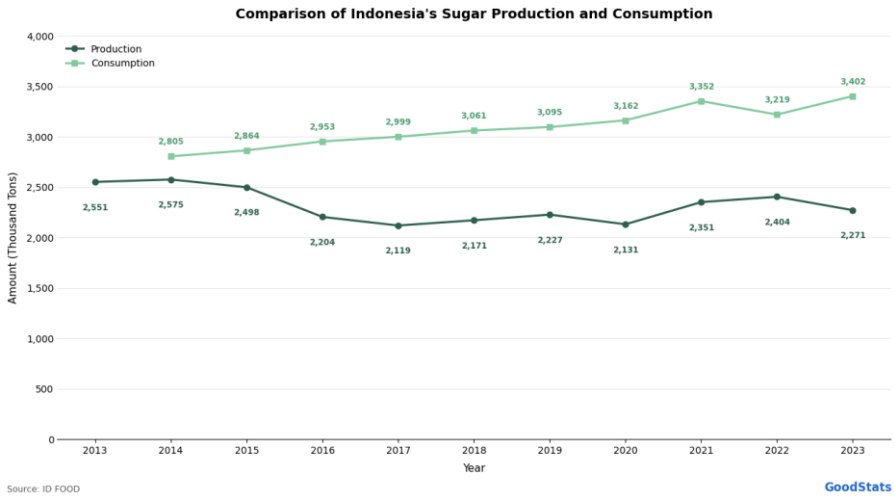

Figure 1. 2 Comparison of Indonesia’s Sugar Production and Consumption
Source: ID Food (Report, 2024)

Complementing this picture, Figure 1.2 illustrates data from the ID Food Report (2024), which documents a widening structural gap between sugar production and consumption in Indonesia. Between 2013 and 2023, national sugar consumption grew steadily from approximately 2.8 million tons to over 3.4 million

tons, while domestic production remained largely stagnant within the range of 2.1 to 2.5 million tons. Left unaddressed, this supply deficit carries significant risks for national food security and threatens to destabilize domestic price levels.

The productivity of the sugar industry is not determined by any single factor but rather emerges from the complex interplay among several key variables: sugarcane quality as feedstock, climatic and seasonal conditions, and the operational performance of machinery and production processes within sugar mills (Adli et al., 2025). Regarding sugarcane quality, attributes such as sucrose content, variety, and harvest maturity directly shape yield potential and overall sugar productivity, as lower-quality cane demonstrably reduces extraction efficiency (Gunawan et al., 2021). Climatic variables introduce additional complexity, as irregular rainfall patterns and unpredictable weather conditions can compromise both sugarcane growth and juice quality, with downstream consequences for yield and output (Hartatie et al., 2021). At the mill level, machinery age, operational disruptions, and suboptimal equipment effectiveness collectively contribute to elevated sugar losses into molasses and reduced effective output (Kurniawan et al., 2021). Taken together, these factors indicate that productivity in the sugar industry extends well beyond the sheer volume of cane processed — it is equally shaped by feedstock quality, environmental adaptability, and the effectiveness with which production technology is deployed.

These operational realities are reflected in the performance of Tjoekir Sugar Mill, one of the production units under PT Sinergi Gula Nusantara, as presented in Table 1.1.

Table 1. 1 Output and Milling Period of PG Tjoekir over the Last 5 Years

Year	Production (tons)	Milling Period (days)
2021	22.126,3	133
2022	28.345,5	134
2023	27.063,3	119
2024	23.244,3	121
2025	34.230,6	168

Source: GKP Production Report, Tjoekir Sugar Mill, 2025

Table 1.1 reveals that Tjoekir Sugar Mill has exhibited considerable fluctuations in productivity over the observed period. Notably, the data suggest that milling duration does not bear a straightforward proportional relationship to output effectiveness. In 2024, for instance, the milling period was extended relative to 2023, yet production volume declined sharply. In contrast, 2025 saw the mill achieve its highest recorded output of 34,230.6 tons over its longest milling period of 168 days. These anomalies point to the necessity of a more rigorous efficiency analysis to determine whether output changes reflect genuine resource optimization or merely the effect of extended operational duration.

This productivity fluctuation mirrors a broader challenge confronting the national sugar industry namely, a persistent imbalance between sugarcane input and sugar output. Despite milling periods that vary between four and six months,

changes in output exhibit no consistent pattern relative to the length of operation. This observation aligns with Yusuf et al. (2020), who found that technical efficiency among sugar mills in East Java remains relatively low due to feedstock quality issues, delays in the milling process, and suboptimal machinery performance. Muhtadi et al. (2024) further demonstrated that sugarcane variety and milling timeliness significantly influence juice purity, extraction yield, and sugar losses into molasses. Tjoekir Sugar Mill was selected as the subject of this study on the basis of its distinguished operational record as one of the highest-performing mills in terms of milling duration and production output within PT Sinergi Gula Nusantara's East Java Regional 2 cluster in 2025 (Hafidz, 2025). Against this backdrop, a systematic quantitative analysis is warranted to objectively determine whether the mill's elevated output represents a genuine improvement in technical efficiency or is attributable primarily to favorable external conditions.

The pattern of output fluctuation and the misalignment between input utilization and production outcomes necessitate an analytical approach capable of distinguishing between quantitative output growth and genuine productive performance improvement. A high sugar output in any given period does not automatically indicate superior technical efficiency, as such figures may be substantially influenced by input extensification whether through larger volumes of cane processed or prolonged operational duration. As argued by Bahruddin (2025), productivity analysis constitutes a critical instrument for assessing the extent to which resources are optimally converted into output, particularly within an industry characterized by its seasonal nature and high resource intensity.

The condition of physical assets particularly aging production machinery is widely regarded as a primary determinant of low productivity in national sugar mills. However, technical efficiency is not solely a function of technological sophistication; it is equally contingent upon management's capacity to pursue operational optimization within existing resource constraints (Marta & Erza, 2017). Through sustained maintenance strategies and the phased rehabilitation of equipment, aging machinery retains the potential to operate at acceptable efficiency levels. In this context, the precise management of inputs in terms of quantity, timing, and intensity of use becomes a decisive factor in determining whether a production system can attain its efficiency frontier.

Data Envelopment Analysis (DEA) is employed in this study for its capacity to evaluate relative technical efficiency by accounting for multiple inputs and outputs simultaneously, without requiring a priori assumptions regarding the form of the production function (Coelli et al., 2005). Specifically, the CCR model (Charnes, Cooper, and Rhodes), which operates under the assumption of Constant Returns to Scale, was selected to measure overall technical efficiency. This model provides an aggregate performance assessment by assuming that each unit increase in input yields a proportional increase in output — an assumption particularly pertinent for evaluating whether Tjoekir Sugar Mill operates at an optimal economic scale, or whether systemic resource waste persists given its current technological constraints.

Conventional DEA analysis is inherently static, offering an efficiency snapshot at a single point in time. To address this limitation, the Malmquist Productivity Index (MPI) is incorporated to measure longitudinal changes in Total Factor Productivity (TFP) across successive periods. The MPI offers a distinct analytical advantage through its decomposition of productivity change into two components: efficiency change, which reflects management's ability to close the gap with the production frontier (the catch-up effect), and technological change, which captures shifts in the frontier itself (Lou et al., 2024). Through the MPI, the performance dynamics of Tjoekir Sugar Mill can be mapped more comprehensively to determine whether the production gains observed in 2025 were driven by improvements in internal governance or by favorable external conditions.

This analysis further supports the mill's pursuit of sustainable operations in alignment with Environmental, Social, and Governance (ESG) principles, wherein improvements in technical efficiency contribute directly to the reduction of material and energy waste (Purnomo et al., 2025). Accordingly, this study focuses on analyzing the productivity and sustainable efficiency of Tjoekir Sugar Mill through the integrated application of DEA-CCR and MPI methodologies, with the aim of formulating operationally relevant recommendations to support the broader strengthening of Indonesia's national sugar industry.

1.2 Problem Statement

Drawing from the issues outlined above, this study seeks to address the following research question:

"To what extent can the technical efficiency and productivity change of Tjoekir Sugar Mill be measured on a sustainable basis through the application of Data Envelopment Analysis (DEA) using the Charnes, Cooper, and Rhodes (CCR) model and the Malmquist Productivity Index (MPI)?"

1.3 Research Objective

This study aims to measure the level of technical efficiency and analyze the sustainable productivity change of Tjoekir Sugar Mill over the period 2021–2025, employing Data Envelopment Analysis (DEA) under the Charnes, Cooper, and Rhodes (CCR) model in conjunction with the Malmquist Productivity Index (MPI). The findings are expected to provide a comprehensive account of the mill's technical performance and Total Factor Productivity (TFP) dynamics, identify production periods characterized by efficiency or inefficiency, and serve as a foundation for formulating operational improvement recommendations particularly with respect to production process optimization and molasses by-product management in support of enhanced productivity and sustainability principles.

1.4 Benefits of the Study

This study is expected to yield meaningful contributions, particularly to the advancement of operational management and productivity analysis within the sugar industry.

1. For Academics

This study is intended to enrich scholarly inquiry in the fields of operational management and productivity analysis, specifically through the application of Data Envelopment Analysis (DEA) and the Malmquist Productivity Index (MPI) within the sugar industry context. Beyond methodological contributions, the study broadens academic perspectives on the importance of incorporating sustainability variables into efficiency frameworks, thereby serving as a comprehensive reference for future research of a similar nature.

2. For the Company

This study is expected to function as a strategic evaluation instrument for the management of Tjoekir Sugar Mill, enabling a systematic mapping of technical performance and productivity achievements over the 2021–2025 period. In doing so, it supports the enhancement of industrial competitiveness and the adoption of operationally sustainable and environmentally responsible practices.

3. For Future Researchers

This study is intended to serve as a methodological reference for subsequent researchers seeking to develop efficiency and productivity analyses within the agro-industrial sector particularly through the expansion of analytical units, extended time horizons, or the more comprehensive integration of environmental and social variables.