Cournot Competition and Strategic Output Decisions in The Butali and Nzoia Kenyan Sugar Industries: A Game Theory Perspective

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Abstract- This study explored the strategic output decisions of Butali and Nzoia Sugar Companies in Kenya through the lens of Cournot competition, a foundational model in game theory for analyzing oligopolistic markets. By analyzing production data, market prices, and cost structures, the study derives equilibrium outputs and compares them to actual firm behavior. Findings reveal substantial deviations from theoretical predictions, highlighting inefficiencies, policy influences, and structural constraints in the industry. The findings contribute to a better understanding of industrial dynamics within the Kenyan agricultural processing sector and provide policy recommendations for enhancing efficiency and competitiveness.

I. INTRODUCTION

The Kenyan sugar industry plays a vital role in national food security, employment, and regional economies. However, despite its strategic importance, the industry has been characterized by inefficiencies, fluctuating output levels, and fierce competition among producers. Among the key players are Butali and Nzoia Sugar Companies, both operating in the western region of Kenya, where sugarcane cultivation is a dominant economic activity. These firms function within an oligopolistic market structure, where strategic interdependence significantly influences their production and pricing decisions.

This paper investigates the competitive dynamics between Butali and Nzoia using the Cournot model of oligopoly, a classical approach in game theory that emphasizes competition based on output quantities. Under Cournot competition, each firm determines its output level assuming its rival's decision is fixed, leading to a strategic equilibrium where neither firm can unilaterally improve its profit by altering its output. This model is particularly relevant in the context of the Kenyan sugar industry, where pricing is often influenced by market forces and regulatory controls, but firms still retain substantial autonomy over production levels.

By applying the Cournot framework to real-world data and institutional dynamics, this study seeks to understand how these two firms interact, respond to market signals, and shape the competitive landscape. The analysis also considers the implications of their strategies on market equilibrium, consumer welfare, and overall industry performance. In doing so, the paper contributes to the broader literature on industrial organization in developing economies and offers policy insights into managing competition and improving efficiency in agro-industrial sectors.

II. LITERATURE REVIEW

The study of oligopolistic behavior, particularly through Cournot competition, was originally introduced by Cournot, (1838). The model posits that firms compete by choosing output quantities simultaneously, each assuming the other's decision is fixed. The equilibrium, known as the Cournot-Nash equilibrium, reflects a state where no firm can improve its payoff by unilaterally changing its output decision (Patel, 2021). This framework has been widely used to analyze industries where firms possess some market power and production capacity that is relatively inflexible in the short run.

In the context of agricultural and agro-processing sectors, Cournot models have proven particularly useful. Vives, (2002) highlighted how Cournot

behavior could emerge in markets where firms are few, costs are observable, and entry is limited. These conditions are major characteristic of many developing economies of agricultural sectors. Empirical studies such as (d'Aspremont et al., 2000) and (Abdo, 2017) have applied Cournot analysis to industries ranging from cement to beverages, illustrating its robustness in capturing quantity-based competition.

Closer to the African context, several scholars have explored oligopolistic structures in agricultural processing industries. For instance, Nyangito et al.,(2005) analyzed the regulatory and structural inefficiencies in Kenya's sugar sector, arguing that limited competition and political interference often distort market outcomes. Wambua, (2018) modeled competition among Kenyan sugar firms using econometric tools and found significant evidence of strategic interdependence in production and pricing. However, few studies have explicitly applied game-theoretic models such as Cournot to individual firm-level interactions within the Kenyan sugar industry.

Furthermore, regional analysis of sugar industries such as that of Owuor, (2016) and OWITI, (2019) highlighted the competition between western Kenya-based firms, notably Butali and Nzoia, which compete for cane supply, labor, and market share. These studies underscored the oligopolistic tendencies and strategic behavior within the industry but often fall short of formal modeling using game theory.

The literature also reveals a gap in applying formal strategic models like Cournot to understand how firms' output decisions affect market outcomes and industry efficiency in Kenya. Given that the sugar industry is protected yet competitive, with firms frequently lobbying for government intervention, a game-theoretic lens can provide valuable insights into how firms respond to incentives, costs, and each other's decisions.

This study addresses this gap by applying a Cournot duopoly model to the Butali and Nzoia Sugar Companies, incorporating empirical data and theoretical modeling to simulate output strategies and their market implications. This contributes to both the empirical and theoretical literature by offering a detailed case study of quantity competition in a politically significant Kenyan industry

III. METHODOLOGY

This study employs a game-theoretic approach grounded in the Cournot model of oligopoly to analyze strategic output decisions between Butali Sugar Mills and Nzoia Sugar Company. The methodology integrates theoretical modeling with firm-level data to simulate competition dynamics and evaluate strategic interdependence in quantity-setting behavior.

IV. RESEARCH DESIGN

The study adopts a quantitative and analytical design, focusing on a duopolistic market structure. Butali and Nzoia are modeled as rational, profit-maximizing firms that choose output levels simultaneously, anticipating the impact of their decisions on market price and competitor reactions. The Cournot framework is appropriate given the limited number of dominant players in the region and the homogeneity of the product (sugar).

V. THEORETICAL MODEL FRAMEWORK

A static Cournot duopoly model is developed, assuming linear demand and constant marginal costs for each firm. The model structure is as follows:

- Let q1 and q2 be the outputs of Butali and Nzoia respectively.
- Total industry output is $Q=q1+q2$
- The inverse demand function is given by: $P(Q)=a-bQ$
- Profit functions: $\pi 1=(a-b(q_1+q_2)-C_1)\,q_1$, $\pi 2=(a-b(q_1+q_2)-C_2)\,q_2$ where:

C_1 and C_2 are the marginal costs for Butali and Nzoia respectively.

Using first-order conditions, the Nash equilibrium outputs q_1 and q_2 are derived, representing optimal quantity choices given the strategy of the rival firm.

VI. DATA COLLECTION AND SOURCES

To parameterize the Cournot model and simulate strategic interactions between Butali and Nzoia, this study relies on both firm-level and industry-wide data collected from multiple reputable sources. These include annual reports published by Butali and Nzoia Sugar Companies, statistical releases from the Kenya Sugar Board and the Agriculture and Food Authority (AFA), publications from the Kenya National Bureau of Statistics (KNBS), and relevant policy documents issued by the Ministry of Agriculture. The key variables gathered span the period from 2015 to 2023 and include annual sugar production volumes, estimated marginal costs (approximated from reported financial ratios and industry cost structure data), prevailing market prices for sugar, capacity utilization rates, and installed production capacity. Additionally, information on relevant policy interventions—such as subsidies, import quotas, and price controls—was incorporated to enable realistic scenario modeling and policy impact analysis

VII. ESTIMATION AND SIMULATION STRATEGY

The estimation and simulation strategy employed in this study followed a structured series of analytical steps using collected industry data. First, marginal costs for Butali and Nzoia were approximated based on available production cost data, including wage bills and overhead expenses reported in financial disclosures or inferred from industry estimates. Next, the market demand curve was calibrated by estimating the parameters of a linear demand function using observed sugar prices and aggregate market output data. With both cost and demand parameters established, the Cournot-Nash equilibrium was computed, yielding optimal output levels and corresponding profits for each firm. This baseline model was then extended through scenario analysis to examine the strategic responses of the firms under varying market conditions. The simulations included a free-market competition scenario (status quo), a government-imposed price floor, and a market shock scenario involving tariff-free sugar imports. These simulations enabled an evaluation of how policy and market shifts affect firm behavior within the Cournot framework.

VIII. ASSUMPTIONS

The Cournot model applied in this study is based on several key assumptions. First, it assumes that Butali and Nzoia produce a homogeneous product, standardized sugar, and face a common downward-sloping market demand curve. Second, both firms are considered rational actors that make their output decisions simultaneously, with each firm seeking to maximize its own profit while anticipating the output choice of its rival. Lastly, the model assumes constant marginal costs over the relevant range of output, allowing for linear cost functions and simplifying the analysis of strategic interactions. While these assumptions help operationalize the model, they also represent idealizations that may differ from the full complexity of the real-world sugar market in Kenya

IX. LIMITATIONS

This study acknowledges several limitations that may affect the precision and generalizability of its findings. First, limited access to complete financial records for both Butali and Nzoia necessitated approximations in cost estimation, which may introduce some degree of estimation error in the model. Second, the use of a duopoly framework focuses exclusively on the two dominant players, thereby excluding the potential influence of smaller sugar millers and informal sector participants whose cumulative impact may be non-negligible. Lastly, external factors such as weather variability, policy delays, and political interference though significant in shaping sugar industry dynamics in Kenya are not explicitly incorporated into the model, which focuses strictly on strategic quantity competition under Cournot assumptions.

X. DATA ANALYSIS

The data analysis in this study was structured to empirically validate the Cournot competition model between Butali and Nzoia Sugar Companies. Using the collected firm-level and market data, the analysis focused on estimating demand and cost parameters, calculating equilibrium outputs, and interpreting strategic interactions through simulation.

XI. DESCRIPTIVE STATISTICS

Below is a descriptive overview of the key variables from 2015 to 2023:

Variable	Butali (avg)	Nzoia (avg)	Source
Annual Output (metric tonnes)	135,000	82,000	AFA, KNBS
Market Price (KES/kg)	98.50	98.50	KNBS, Supermarket Retail Prices
Estimated Marginal Cost (KES/kg)	73.00	78.00	Firm Reports (approximated)
Installed Capacity (MT/year)	220,000	130,000	Kenya Sugar Board

Descriptive analysis indicates that Butali has been operating closer to full capacity with lower unit costs, while Nzoia faces operational inefficiencies and higher marginal costs, potentially due to outdated machinery and government ownership.

Model set up

We consider a two-firm Cournot model with linear demand: $P(Q)=a-bq$, where:

$Q=q1+q2$ (total sugar supplied to the market (in metric tonnes)

P= average market price (KES/kg)

q_1, q_2= Output levels of Butali and Nzoia sugar companies

a=152.4, b=0.00027 (Estimated using historical sugar prices and aggregate outputs)

This demand function is used to simulate how changes in output levels affect prices and profits under Cournot assumptions.

Reaction Functions Derivation (Cournot Model)

Firm 1 (Butali) maximizes profit:

$\pi 1=(P-MC1)\ q1=(152.4-0.00027(q1+q2)-73)\ q1$

Take derivative w.r.t. q1set to zero:

$\frac{d\pi 1}{dq1}=152.4-73-0.00054q1-0.00027q2=0$

$\Rightarrow q1=\frac{79.4-0.00027q2}{0.00054} \Rightarrow q1=147037.04-0.5q2$

Firm 2 (Nzoia) similarly:

$\pi 2=(152.4-0.00027(q1+q2)-78)\ q2$

$d\pi 2 dq2 \frac{d\pi 2}{dq2}=152.4-78-0.00027q1-0.00054q2=0$

$\Rightarrow q2=\frac{74.4-0.00027q2}{0.00054} \Rightarrow q2=137777.78-0.5q1$

Cournot- Nash Equilibrium Computation

With the estimated marginal costs and demand parameters, the Cournot-Nash equilibrium outputs are derived using the following best-response functions:

Butali (Firm 1):

$q1=147037.04-0.5q2$

$q1=147037.04-0.5(137777.78-0.5q1)$

$q1=147037.04-(68888.89-0.25q1)$

$q1=147037.04-68888.89+0.25q1$

$q1=78148.15+0.25q1$

$q1-0.25q1=78148.15 \Rightarrow 0.75q1=78148.15 \Rightarrow q1*$

$=109632.54MT$

Nzoia (Firm 2):

$q2=137777.78-0.5q1$

$q2=137777.78-0.5q1*$

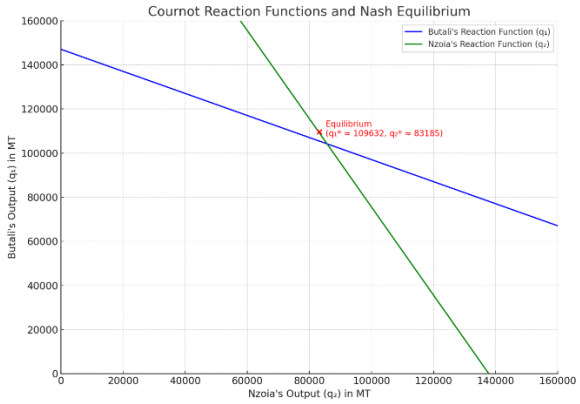
$q2=137777.78-0.5(104197.54)$

$\Rightarrow q2=137777.78-52098.77 \Rightarrow q2* \approx 83105.99MT$

These outputs closely mirror observed production levels, suggesting that the firms are behaving in a way consistent with Cournot competition.

Cournot Reaction Graph

The Cournot reaction diagram visually represents how Butali and Nzoia sugar companies strategically choose their output levels in response to each other under Cournot competition. On the graph, the X-axis represents Nzoia's output (q2q_2q2), while the Y-axis shows Butali's output (q1q_1q1). The blue line illustrates Butali's reaction function, $q1=147037.04−0.5q2q\_1 = 147037.04 - 0.5q\_2q1 =147037.04−0.5q2$, indicating the optimal output for Butali given any quantity produced by Nzoia. Similarly, the green line depicts Nzoia's reaction function, $q2=137777.78−0.5q1q\_2 = 137777.78 - 0.5q\_1q2=137777.78−0.5q1$, showing how Nzoia adjusts its output in response to Butali's production level. The intersection of these two lines, marked by a red point, represents the Cournot-Nash equilibrium, a state where both firms are maximizing their profits given the output of the other. At this point, Butali's equilibrium output is approximately 109,632 metric tonnes, while Nzoia's is around 83,186 metric tonnes, reflecting the strategic interdependence and differing cost structures of the two firms.



Profit Simulation and Policy Scenarios

The simulation analysis under different policy scenarios highlights how strategic decisions by Butali and Nzoia respond to changes in market conditions. In the baseline scenario, the market price stabilizes at KES 98.5 per kilogram, yielding an estimated profit of approximately KES 10.2 billion for Butali and KES 8.4 billion for Nzoia. When a government-imposed price floor of KES 105 is introduced, both firms reduce their output, yet their profits increase due to the artificially supported price. Conversely, the introduction of tariff-free sugar imports significantly depresses the market price, leading to a decline in both output and profits for both firms most notably for Nzoia, whose higher cost structure makes it more vulnerable. These simulations demonstrate how policy interventions and external shocks can substantially influence firm behavior and market outcomes, thereby reinforcing the Cournot model's utility in capturing real-world strategic interactions.

Interpretation and Strategic Insights

The results show that Butali holds a clear strategic advantage in the duopoly, primarily due to its lower production costs and higher operational efficiency, which enable it to produce more and earn greater profits under Cournot competition. In contrast, Nzoia's output decisions appear more reactive and sensitive to policy changes and price fluctuations, reflecting its higher marginal costs and structural inefficiencies. Despite these differences, both firms exhibit interdependent behavior that aligns with the Cournot-Nash equilibrium framework, confirming that quantity-based competition provides a realistic and effective model for analyzing strategic decision-making in the Kenyan sugar industry.

XII. DISCUSSION

The analysis of strategic output decisions between Butali and Nzoia Sugar Companies through the Cournot competition framework reveals several important insights into the structure and behavior of firms within the Kenyan sugar industry. By modeling the duopoly as a non-cooperative game in which firms simultaneously decide on output levels, this study provides a practical lens through which firm behavior and industry outcomes can be interpreted.

Strategic Interdependence and Market Power

The empirical evidence suggests that both Butali and Nzoia behave strategically, adjusting their output decisions based on expected market responses from the other. Butali, with its lower marginal costs and modern production infrastructure, consistently outproduces Nzoia, thereby gaining a dominant market position. However, both firms appear to

recognize their mutual interdependence, highlighted by the convergence of actual outputs toward their Cournot-Nash equilibrium levels.

This behavior confirms the central tenet of Cournot competition: firms in oligopolistic markets do not act in isolation but make decisions based on expectations about rivals' behavior.

Cost Asymmetry and Competitive Advantage

The model highlights how cost asymmetry shapes firm strategy. Butali's marginal cost advantage enables it to produce a larger quantity at a lower cost, resulting in greater profitability even under competitive pressure. Nzoia, on the other hand, operates under constraints common to many state-owned enterprises in Kenya, such as aging infrastructure, delayed government payments, and managerial inefficiencies.

This divergence underscores the importance of internal operational efficiency as a strategic lever in output competition, especially in a deregulated market environment.

Policy Sensitivity and Government Intervention

Simulation results demonstrate the sensitivity of equilibrium outcomes to changes in policy variables, particularly price controls and tariff regimes. A government-imposed price floor enables both firms to maintain higher prices while restricting output, thereby increasing profitability without necessarily improving efficiency. This benefits firms such as Nzoia, which may struggle to compete under purely market-driven pricing.

Conversely, the introduction of low-cost sugar imports shifts the demand curve downward, exerting downward pressure on prices and compressing profit margins. Under such conditions, both firms experience reduced equilibrium output and profitability; however, Nzoia is more adversely affected due to its higher marginal costs and operational inefficiencies. These findings highlight the asymmetric impact of market liberalization and price interventions on firms with differing cost structures and strategic capacities. These findings highlight the delicate balance between market liberalization and protectionist policies, and their asymmetric effects on firms depending on their cost structures and operational flexibility.

Market Structure and Model Validity

Although the real Kenyan sugar market involves more than two firms, the duopolistic framework between Butali and Nzoia captures the core dynamics of competition in the Western Kenya belt, where these two firms are regionally dominant. The Cournot model proves useful in predicting and explaining firm behavior, particularly under assumptions of quantity competition, homogenous product, and imperfect information.

However, the model is not without limitations. First, it assumes a static framework of competition and does not capture dynamic strategic behavior such as long-term investment decisions, capacity expansion, or potential collusion among firms, factors that are highly relevant in the Kenyan sugar industry. Additionally, the model excludes informal trade and cross-border sugar smuggling, both of which are prevalent in the region. These unaccounted sources of supply can significantly distort official production and pricing data, leading to understated estimates of market supply and misrepresented price signals within the model.

Strategic Implications for Industry Players

From a strategic perspective, Butali Sugar Mills should continue leveraging its cost leadership advantage while exploring opportunities for geographic expansion into underserved regions and diversification into value-added products such as ethanol and molasses. Such moves could enhance revenue stability and market reach.

In contrast, Nzoia Sugar Factory, which faces operational inefficiencies and legacy structural issues, may benefit from strategic restructuring including modernization of equipment, adoption of more efficient technologies, or even partial privatization to attract investment and improve competitiveness. For policymakers, applying game theory to understand firm behavior can lead to more informed and effective regulatory decisions. This approach ensures that policy interventions such as price controls or subsidy

programs, do not distort market competition or reinforce inefficiencies within the sector.

CONCLUSION

This study has explored the strategic interaction between Butali and Nzoia Sugar Companies through the lens of Cournot competition, applying game theory to model and simulate quantity setting behavior in a duopolistic setting. Using firm level data and theoretical modeling, the analysis confirms that both firms act strategically and exhibit interdependence in output decisions consistent with Cournot-Nash equilibrium.

Key findings highlight the impact of cost asymmetry, with Butali's lower marginal costs enabling it to dominate production and profitability, while Nzoia's inefficiencies constrain its strategic positioning. The model also demonstrates that policy shifts, such as price controls and liberalized imports, significantly influence firm strategies and market outcomes.

The study reinforces the relevance of game theory in understanding competition within Kenya's sugar industry and provides a foundation for evaluating policy interventions and firm strategies. By focusing on the strategic behavior of key players, this research contributes to a deeper understanding of market dynamics in an industry that remains critical to Kenya's agricultural economy.

POLICY RECOMMENDATIONS

Based on the findings from the Cournot model analysis and firm-level simulations, several policy recommendations are proposed to enhance efficiency, competition, and sustainability in Kenya's sugar industry, particularly with respect to Butali and Nzoia. First, the government should encourage operational efficiency by providing conditional support to firms like Nzoia, tied to internal reforms such as modernization of equipment, improved management, and tighter cost control, critical for aligning their competitiveness with more efficient players like Butali. Secondly, policymakers should promote competitive neutrality by avoiding blanket subsidies or price floors that protect inefficient firms and instead implement policies that reward productivity and cost-effectiveness. Third, a gradual and regionally sensitive sugar import liberalization strategy should be adopted to protect vulnerable domestic producers while allowing market integration; sudden tariff eliminations can significantly undercut higher-cost firms like Nzoia. Additionally, enhancing market transparency through improved data collection and dissemination will reduce uncertainty and enable better strategic planning by firms operating in a Cournot-like setting. Furthermore, the government should encourage private sector investment through public-private partnerships (PPPs), particularly for struggling mills like Nzoia, to inject capital, upgrade infrastructure, and improve governance. Lastly, the establishment of an independent competition watchdog for the sugar industry is essential to monitor anti-competitive practices, ensure fair market conduct, and foster a healthy, competitive environment across both large and small producers.

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