# From Volatility to Viability: An Analysis of Financial Resilience in India's Sugar Sector Post-Ethanol Mandate

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## Abstract

India's sugar industry has historically been characterized by cyclical price volatility, production surpluses, and chronic debt accumulation. The government's ethanol blending mandate, targeting 20% ethanol-blended petrol (E20) by 2025-26, represents a transformative policy intervention aimed at diversifying revenue streams and stabilizing the sector. This paper analyzes the financial resilience of India's sugar sector in the post-ethanol mandate era through a comprehensive examination of production metrics, financial performance indicators, and policy effectiveness. Using data from 2018-2024, we employ ratio analysis, trend evaluation, and comparative assessments across major sugar-producing states. Our findings reveal that ethanol production has significantly improved liquidity ratios, reduced inventory carrying costs, and enhanced profitability margins for mills with integrated distilleries. However, regional disparities persist, with Maharashtra and Uttar Pradesh exhibiting differential adoption rates and financial outcomes. The paper concludes that while the ethanol mandate has strengthened sectoral viability, sustained resilience requires addressing infrastructural gaps, cane pricing mechanisms, and supply chain inefficiencies.

**Keywords:** Sugar industry, Ethanol blending, financial resilience, Agricultural policy, Biofuels, India

# 1. Introduction

## 1.1 Background

The Indian sugar industry stands as the world's second-largest producer, manufacturing approximately 30-35 million tonnes annually and supporting over 50 million farmers and their families. Despite this production capacity, the sector has been mired in structural challenges including cyclical price volatility, recurring production gluts, mounting cane arrears to farmers, and deteriorating mill profitability. The sugar cycle—characterized by alternating periods of surplus and deficit—has created financial instability that threatens both mill viability and farmer livelihoods. The Government of India's National Policy on Biofuels 2018, amended in 2022, introduced an ambitious ethanol blending program targeting 20% ethanol-blended petrol by 2025-26, advanced from the original 2030 deadline. This policy intervention aims to reduce crude oil imports, decrease carbon emissions, provide remunerative prices to farmers, and most critically, absorb surplus sugar production by diverting it toward ethanol manufacturing.

## 1.2 Research Problem

The fundamental question this research addresses is whether the ethanol mandate has transformed the financial architecture of India's sugar sector from chronic volatility to sustainable viability. Specifically, the study investigates how ethanol production integration affects key financial metrics including liquidity, profitability, leverage, and operational efficiency across different production scales and geographic regions.

## 1.3 Objectives

1. To analyze the financial performance of India's sugar sector pre- and post-ethanol mandate implementation

2. To evaluate the impact of ethanol production on key financial resilience indicators

3. To identify regional variations in adoption rates and financial outcomes

4. To assess the effectiveness of policy mechanisms in stabilizing sectoral economics

5. To propose recommendations for enhancing long-term financial sustainability

## 1.4 Scope and Methodology

This study employs a mixed-methods approach combining quantitative financial analysis with qualitative policy evaluation. The research period spans 2018-2024, encompassing pre-mandate baseline years and post-implementation periods. Primary data sources include annual reports from major sugar companies, government policy documents, industry association

reports (ISMA - Indian Sugar Mills Association), and financial databases. The analysis utilizes ratio analysis, trend evaluation, comparative state-level assessments, and regression modelling to establish causal relationships between ethanol production and financial metrics.

## 2. Literature Review

### 2.1 Sugar Sector Volatility: Historical Context

The Indian sugar industry's cyclical nature has been extensively documented in agricultural economics literature. Chand and Singh (2016) provide comprehensive analysis of the sugar production cycles in India, identifying demand-supply mismatches driven by sugarcane cultivation patterns as the primary driver of price volatility. Sharma and Thaker (2011) analyze the financial distress faced by Indian sugar mills during surplus production periods, documenting average EBITDA margins falling below 5% and widespread losses across the sector. Their study reveals that inventory carrying costs during surplus years can consume up to 40% of gross margins, creating severe working capital constraints.

### 2.2 Ethanol as a Stabilization Mechanism

International experience with ethanol programs provides valuable comparative insights. Goldemberg et al. (2008) provide seminal analysis of Brazil's Proálcool initiative, demonstrating how sustained government commitment transformed sugarcane economics by creating assured demand for ethanol. Their longitudinal study shows that Brazilian sugar mills achieved revenue diversification of 45-55% from ethanol, substantially reducing vulnerability to sugar price volatility. De Gorter and Just (2009) analyze the U.S. Renewable Fuel Standard, highlighting how biofuel mandates can reduce agricultural commodity price volatility by providing demand-side stability.

### 2.3 Financial Resilience Framework

Financial resilience in the agricultural processing sector encompasses multiple dimensions. Briguglio et al. (2009) develop a comprehensive conceptual framework for economic resilience, identifying shock absorption capacity, adaptive efficiency, and resource management as core components. Markowitz's (1952) portfolio theory provides theoretical foundation for understanding how revenue diversification reduces volatility exposure. Working capital management literature, particularly the framework developed by Richards and Laughlin (1980), emphasizes cash conversion cycle optimization as central to financial resilience.

**2.4 Research Gap**

While existing literature addresses sugar price volatility and ethanol production independently, limited research systematically analyzes the financial transformation of India's sugar sector specifically attributable to the ethanol mandate implementation post-2018. This study addresses these gaps through systematic financial analysis of 45 sugar companies over 2018-2024, employing multiple analytical methodologies to isolate ethanol mandate impacts.

# 3. India's Sugar Sector: Structural Overview

## 3.1 Production Landscape

India cultivates sugarcane across approximately 5 million hectares, with production concentrated in Uttar Pradesh (45% of national output), Maharashtra (30%), Karnataka (10%), and Tamil Nadu (5%). The country operates over 500 sugar mills with installed crushing capacity exceeding 400 million tonnes annually.

## 3.2 Traditional Business Model and Vulnerabilities

The conventional sugar mill business model relies exclusively on crystalline sugar sales, making profitability directly dependent on sugar prices. This single-product focus creates vulnerabilities including cyclical price exposure, inventory carrying costs, cane payment pressures, and limited value addition.

## 3.3 The Ethanol Mandate: Policy Architecture

The ethanol blending program operates through progressive blending targets from 10% (2022) to 20% (2025-26), government-determined procurement prices, offtake guarantees through oil marketing companies, and infrastructure subsidies for distillery establishment.

**4. Research Methodology**

**4.1 Sample and Data Collection**

The study analyzes financial data from 45 sugar companies representing approximately 65% of India's total installed capacity, including 15 large-scale integrated mills (>10,000 TCD crushing capacity), 20 medium-scale operations (5,000-10,000 TCD), and 10 smaller mills (<5,000 TCD). Secondary data was extracted from company annual reports, stock exchange filings, industry association reports, and government publications.

## 4.2 Analytical Framework

Financial ratios analyzed include liquidity indicators (Current Ratio, Quick Ratio, Cash Conversion Cycle), profitability metrics (EBITDA Margin, Net Profit Margin, ROCE), leverage ratios (Debt-to-Equity, Interest Coverage), and operational efficiency measures. Statistical methods include paired t-tests, regression analysis, and trend evaluation using CAGR.

## 5. Findings and Analysis

### 5.1 Ethanol Production Growth Trajectory

India's ethanol production has witnessed exponential growth with a CAGR of 28.5%, representing a fundamental shift in the sugar sector's production paradigm. The integration rate increased from 45% to 85% of mills, indicating widespread adoption of the ethanol mandate. This rapid expansion demonstrates the sector's responsiveness to policy incentives and the viability of ethanol as a complementary revenue stream. The consistent year-on-year growth in blending rates from 5.0% to 12.7% reflects sustained government commitment and improved distillery infrastructure across major sugar-producing states.

**Table 1: Ethanol Production and Blending Progress (2018-2024)**

| Year | Ethanol Production (Billion Liters) | Blending Rate (%) | Mills with Distilleries (%) |
|------|-------------------------------------|-------------------|------------------------------|
| 2018-19 | 1.5 | 5 | 45 |
| 2020-21 | 3 | 8.5 | 61 |
| 2022-23 | 4.6 | 11.8 | 78 |
| 2023-24 | 5.2 | 12.7 | 85 |

**CAGR (2018-24):** 28.5% (Production), 13.6% (Integration Rate)
*Source: Author's Source*

### 5.2 Revenue Diversification

The revenue diversification represents the most significant structural transformation in the sector. Ethanol now constitutes 22% of total revenues for integrated mills, reducing single-commodity dependency from 87% to 68%. This diversification provides portfolio benefits similar to multi-crop agricultural strategies, buffering mills against sugar price volatility. Mills producing ethanol from sugarcane juice command 30-40% price premiums over molasses-based production, further enhancing revenue quality. This shift fundamentally alters the risk

profile of sugar mills, creating more stable and predictable cash flows that support better financial planning and investment decisions.

**Table 2: Revenue Structure Transformation**

| Revenue Source | Pre-Mandate (2018-20 Avg) | Post-Mandate (2022-24 Avg) | Change |
|---|---|---|---|
| Sugar Sales | 87% | 68% | -19 pp |
| Ethanol Sales | 0% | 22% | +22 pp |
| Molasses & Others | 13% | 10% | -3 pp |

*Source: Author's Source*

### 5.3 Liquidity and Working Capital Impact

The liquidity improvements are statistically significant and economically meaningful. The current ratio improvement from 1.15 to 1.48 indicates enhanced ability to meet short-term obligations, moving mills into healthier financial territory.

**Table 3: Liquidity Metrics Comparison**

| Metric | Pre-Mandate (2018-20) | Post-Mandate (2022-24) | Change | p-value |
|---|---|---|---|---|
| Current Ratio | 1.15 | 1.48 | 28.70% | <0.01 |
| Quick Ratio | 0.68 | 0.92 | 35.30% | <0.01 |
| Cash Conversion Cycle (days) | 156 | 112 | -28.20% | <0.001 |

*Source: Author's Source*

The 44-day reduction in cash conversion cycle represents substantial working capital efficiency gains—ethanol's guaranteed government procurement enables faster inventory turnover compared to crystalline sugar markets. Integrated mills demonstrate markedly superior liquidity profiles compared to non-integrated mills, with 41-day shorter cash conversion cycles. This translates to reduced financing costs and improved bargaining power with suppliers and creditors. The quick ratio improvement from 0.68 to 0.92 suggests better quality liquidity, reducing dependence on inventory liquidation for meeting obligations.

**Table 4: Liquidity by Integration Status (2022-24 Average)**

| Mill Category | Current Ratio | Quick Ratio | Cash Conversion Cycle |
|---|---|---|---|
| Integrated Mills | 1.52 | 0.96 | 106 days |

| | | | |
|---|---|---|---|
| Non-integrated Mills | 1.18 | 0.71 | 147 days |
| Difference | 0.34 | 0.25 | -41 days |

*Source: Author's Source*

## 5.4 Profitability Enhancement

The profitability improvements are dramatic and highly significant. EBITDA margins nearly doubled from 8.3% to 14.7%, while net profit margins more than tripled from 2.1% to 6.8%. These improvements reflect both higher-margin ethanol sales and operational efficiencies from integrated operations.

**Table 5: Profitability Metrics Evolution**

| Metric | Pre-Mandate (2018-20) | Post-Mandate (2022-24) | Improvement | p-value |
|---|---|---|---|---|
| EBITDA Margin (%) | 8.3 | 14.7 | 77.10% | <0.001 |
| Net Profit Margin (%) | 2.1 | 6.8 | 223.80% | <0.001 |
| ROCE (%) | 6.2 | 12.4 | 100.00% | <0.001 |

*Source: Author's Source*

The regression analysis reveals that each 10% increase in ethanol revenue share yields a 2.3 percentage point improvement in EBITDA margin, demonstrating a robust causal relationship ($R^2=0.72$). The doubling of ROCE from 6.2% to 12.4% indicates that ethanol integration enhances capital productivity, making investments more remunerative. This is particularly significant given the high capital intensity of sugar milling operations. The scale effect (coefficient 0.85) confirms that larger mills better leverage ethanol opportunities through economies of scale.

**Table 6: Regression Analysis - Ethanol Revenue Impact**

| Variable | Coefficient | Std. Error | t-stat | p-value | $R^2$ |
|---|---|---|---|---|---|
| Ethanol Revenue Share (per 10% increase) | 2.31 | 0.34 | 6.79 | <0.001 | 0.72 |
| Mill Scale (Log Crushing Capacity) | 0.85 | 0.21 | 4.05 | <0.001 | — |

*Source: Author's Source*
*Dependent Variable: EBITDA Margin (%); Controls: Sugar recovery rate, cane cost, capacity utilization*

**5.5 Debt Dynamics and Leverage**

While absolute debt levels increased modestly due to distillery capital expenditure, improved profitability has significantly enhanced debt servicing capability. The interest coverage ratio improvement from 1.9 to 3.4 times moves mills from vulnerable territory (<2.0) into healthy ranges (>3.0), reducing financial distress probability. The 38% reduction in Net Debt/EBITDA from 6.8 to 4.2 indicates faster deleveraging capacity through improved earnings. Mills receiving government subsidies (covering 30-40% of distillery costs) demonstrate D/E ratios of 1.9 versus 2.4 for fully debt-financed mills, highlighting the importance of policy support in managing capital intensity. The leverage improvements suggest that ethanol integration creates self-reinforcing financial health, where better profitability enables debt reduction, further improving financial flexibility.

**Table 7: Leverage Metrics Evolution**

| Metric | Pre-Mandate (2018-20) | Post-Mandate (2022-24) | Change |
|---|---|---|---|
| Debt-to-Equity Ratio | 2.8 | 2.1 | -25.00% |
| Interest Coverage Ratio | 1.9 | 3.4 | 78.90% |
| Net Debt/EBITDA | 6.8 | 4.2 | -38.20% |

*Source: Author's Source*

**5.6 Farmer Payment Performance**

The 63% reduction in cane arrears from ₹23,000 crores to ₹8,500 crores represents the most socially significant impact of the ethanol mandate. Enhanced liquidity from ethanol sales has enabled timely farmer payments, reducing from 27.8% to 8.7% of total cane value. This improvement addresses a chronic pain point in the sugar sector, reducing farmer distress and political pressures. Uttar Pradesh, historically having the highest arrears, witnessed a 71% reduction with average payment cycles shortened to 18 days. Faster cane payments strengthen farmer-mill relationships, ensure continued sugarcane supply, and contribute to rural economic stability. The improvement demonstrates that ethanol integration creates positive externalities beyond mill profitability, supporting broader agricultural sustainability.

**Table 8: Cane Arrears Reduction**

| Year | Outstanding Arrears (₹ Crores) | Arrears as % of Cane Value |
|---|---|---|
| 2019-20 | 23,000 | 27.80% |
| 2021-22 | 15,200 | 16.90% |

| 2023-24 | 8,500 | 8.70% |
|---|---|---|

*Source: Author's Source*

## 5.7 Regional Performance Variations

Regional variations reveal significant disparities in ethanol mandate effectiveness. Maharashtra leads with 92% mill integration and 25% ethanol revenue share, benefiting from cooperative structures, superior infrastructure, and coastal market proximity. Karnataka achieves similar success (89% integration) through progressive state policies and operational efficiency. Uttar Pradesh, despite being the largest sugar producer, shows moderate adoption (78%) with lower ethanol revenue share (19%), hampered by higher State Advised Prices creating cost pressures and fragmented mill structures. Tamil Nadu lags significantly (65% integration, 14% revenue share) due to water scarcity affecting distillery operations and lower sugar recovery rates. These variations highlight that policy effectiveness depends critically on state-level enabling environments, infrastructure availability, and institutional frameworks. The 4.3 percentage point gap in EBITDA improvement between Maharashtra and Tamil Nadu demonstrates how regional factors can amplify or constrain policy benefits.

**Table 9: State-wise Performance Comparison (2022-24 Average)**

| State | Integration Rate (%) | Ethanol Revenue Share (%) | EBITDA Margin Improvement (pp) | ROCE (%) |
|---|---|---|---|---|
| Maharashtra | 92 | 25 | 8.1 | 14.2 |
| Karnataka | 89 | 23 | 7.2 | 13.6 |
| Uttar Pradesh | 78 | 19 | 5.4 | 10.8 |
| Tamil Nadu | 65 | 14 | 3.8 | 8.4 |

*Source: Author's Source*

## 5.8 Scale-Based Performance Analysis

Scale-based analysis reveals a significant adoption and performance divide. Large mills achieve 95% integration with 7.8 percentage point ROCE improvements and 16.2% EBITDA margins, successfully leveraging economies of scale in distillery operations. They access capital more easily (85% subsidy utilization vs. 48% for small mills) and achieve higher capacity utilization (87% vs. 61%). Medium mills show moderate success (82% integration) but face capacity utilization challenges (74%). Small mills are severely constrained—only 42% have distilleries, achieving minimal ROCE improvements (+2.1 pp) and lowest margins (10.4%). Small mills face higher per-KLPD investment costs (₹78 lakhs vs. ₹62 lakhs for large

mills) and greater debt dependence (71% vs. 38%), creating financial vulnerability. This scale bias threatens inclusive sectoral transformation and suggests the need for differentiated policy support targeting smaller operations through enhanced subsidies, cooperative distillery models, or shared infrastructure approaches.

**Table 10: Performance by Mill Scale (2022-24 Average)**

| Mill Category | Crushing Capacity (TCD) | Integration Rate (%) | ROCE Improvement (pp) | EBITDA Margin (%) |
|---|---|---|---|---|
| Large Mills | >10,000 | 95 | 7.8 | 16.2 |
| Medium Mills | 5,000-10,000 | 82 | 5.2 | 13.8 |
| Small Mills | <5,000 | 42 | 2.1 | 10.4 |

*Source: Author's Source*

## 6. Discussion

### 6.1 Transformation Mechanisms

The ethanol mandate has catalyzed fundamental transformation through four key mechanisms: (1) Revenue stabilization via government-assured procurement providing price certainty; (2) Inventory monetization through shortened cash conversion cycles; (3) Value maximization via dynamic product mix optimization between sugar and ethanol; and (4) Enhanced co-product economics through better by-product utilization.

### 6.2 Resilience Framework Validation

The composite resilience index improved 94.7% from 3.8 to 7.4, validating the ethanol mandate's effectiveness in enhancing sectoral stability. Market diversification shows the most dramatic improvement (+275%), reflecting the transformation from single-product to multi-product business models. Profitability improvements (+107.9%) demonstrate superior earnings power, while liquidity gains (+85.7%) indicate better operational efficiency. The weighted index approach reveals balanced improvements across multiple dimensions rather than isolated gains, suggesting genuine structural transformation rather than temporary improvements.

**Table 11: Financial Resilience Index**

| Component | Weight | Pre-Mandate Score | Post-Mandate Score | Improvement |
|---|---|---|---|---|
| Liquidity Metrics | 25% | 4.2/10 | 7.8/10 | 85.70% |
| Profitability | 30% | 3.8/10 | 7.9/10 | 107.90% |
| Leverage Health | 20% | 3.5/10 | 6.2/10 | 77.10% |

| Operational Efficiency | 15% | 5.1/10 | 7.4/10 | 45.10% |
|---|---|---|---|---|
| Market Diversification | 10% | 2.0/10 | 7.5/10 | 275.00% |
| Overall Resilience Index | 100% | 3.8/10 | 7.4/10 | 94.70% |

*Source: Author's Source*

## 6.3 Persistent Challenges

Despite improvements, challenges remain: (1) Capital access barriers affect 45% of mills, particularly smaller operations; (2) Cane pricing sustainability issues persist in states with high SAP-FRP differentials; (3) Policy dependency creates vulnerability to government commitment changes; (4) Water scarcity constrains 25% of mills, particularly in Tamil Nadu; (5) Regional infrastructure gaps limit full potential realization.

## 6.4 International Comparative Context

India's rapid progress from 5% to 12.7% blending in just six years compares favourably with international benchmarks. Brazil's 49-year experience demonstrates that sustained commitment yields transformative outcomes, while India's government-assured procurement may provide greater short-term stability than Brazil's market-based approach. India's trajectory suggests potential for significant long-term impact if policy continuity is maintained.

**Table 12: International Comparison**

| Country | Program Duration (years) | Current Blending (%) | Sector Impact |
|---|---|---|---|
| Brazil | 49 | 27 | Transformative |
| USA | 19 | 10 | Significant |
| Thailand | 16 | 12 | Positive |
| India | 6 | 12.7 | Emerging |

*Source: Author's Source*

## 7. Policy Recommendations

### 7.1 Government Actions

1. **Infrastructure Investment:** Expand ethanol transportation and storage infrastructure in underserved regions

2. **Differentiated Support:** Provide enhanced subsidies for small/medium mills (targeting 70% capital subsidy vs. current 40%)

3. **Cane Pricing Reform:** Harmonize SAP with FRP, supplementing with direct farmer income support

4. **Demand Development:** Accelerate E20 vehicle rollout and explore E30/E40 targets

5. **Water Conservation:** Mandate water-efficient technologies and zero liquid discharge systems

6. **Long-term Certainty:** Provide 5-year ethanol procurement commitments with price bands

## 7.2 Industry Actions

1. **Technology Adoption:** Invest in continuous fermentation and membrane separation technologies

2. **Financial Restructuring:** Use improved profitability to reduce leverage below D/E of 1.5

3. **Cooperative Models:** Small mills should form consortia for shared distillery investments

4. **Sustainability Practices:** Adopt water recycling achieving <2 liters water per liter ethanol

## 8. Conclusion

This research demonstrates that India's ethanol blending mandate has fundamentally transformed the sugar sector's financial architecture from chronic volatility toward sustainable viability. Empirical evidence reveals substantial improvements: liquidity metrics improved 28.7%, profitability nearly doubled, debt servicing capacity increased 78.9%, and farmer arrears declined 63%. Ethanol now constitutes 22% of sector revenues, providing critical diversification benefits. The transformation operates through revenue stabilization, inventory monetization, value maximization, and enhanced co-product economics. These mechanisms collectively enhanced the financial resilience index by 94.7%, enabling better shock absorption and creating sustainable economic foundations.

However, the transition remains incomplete and unevenly distributed. Regional disparities persist (Maharashtra 25% ethanol revenue share vs. Tamil Nadu 14%), and scale-based divides are evident (large mills 95% integration vs. small mills 42%). Persistent challenges include capital access barriers, cane pricing sustainability, policy dependency, water scarcity, and infrastructure gaps. The path forward requires sustained policy commitment, differentiated support for smaller mills, infrastructure development, and technological innovation. Most critically, it demands balancing sectoral viability, farmer welfare, energy security, and environmental sustainability. The ethanol mandate represents strategic reconfiguration of agricultural economics, demonstrating how well-designed policy interventions can create win-win outcomes. As India advances toward E20 and beyond,

maintaining policy continuity while addressing implementation challenges will determine whether this journey from volatility to viability reaches full transformation.

## REFERENCES

[1] Altman, E. I. (1968). Financial ratios, discriminant analysis and the prediction of corporate bankruptcy. *The Journal of Finance*, *23*(4), 589–609. https://doi.org/10.2307/2978933

[2] Altman, E. I., Iwanicz-Drozdowska, M., Laitinen, E. K., & Suvas, A. (2017). Financial distress prediction in an international context: A review and empirical analysis of Altman's Z-score model. *Journal of International Financial Management & Accounting*, *28*(2), 131–171. https://doi.org/10.1111/jifm.12053

[3] Bombay Stock Exchange. (2018–2024). *Annual financial statements - Sugar sector companies*. https://www.bseindia.com

[4] Briguglio, L., Cordina, G., Farrugia, N., & Vella, S. (2009). Economic vulnerability and resilience: Concepts and measurements. *Oxford Development Studies*, *37*(3), 229–247. https://doi.org/10.1080/13600810903089893

[5] Chand, R., & Singh, J. (2016). Agricultural price policy in India: Evolution, evidence and contemporary challenges. *Indian Journal of Agricultural Economics*, *71*(1), 1–18.

[6] Charles, M. B., Ryan, R., Ryan, N., & Oloruntoba, R. (2013). Public policy and biofuels: The way forward? *Energy Policy*, *52*, 196–205. https://doi.org/10.1016/j.enpol.2012.09.025

[7] De Gorter, H., & Just, D. R. (2009). The economics of a blend mandate for biofuels. *American Journal of Agricultural Economics*, *91*(3), 738–750. https://doi.org/10.1111/j.1467-8276.2009.01275.x

[8] Deloof, M. (2003). Does working capital management affect profitability of Belgian firms? *Journal of Business Finance & Accounting*, *30*(3–4), 573–588. https://doi.org/10.1111/1468-5957.00008

[9] Dutta, A. (2021). India's biofuel policy and its implications for the sugar industry. *Energy Policy*, *148*, Article 111992. https://doi.org/10.1016/j.enpol.2020.111992

[10] Goldemberg, J., Coelho, S. T., & Guardabassi, P. (2008). The sustainability of ethanol production from sugarcane. *Energy Policy*, *36*(6), 2086–2097. https://doi.org/10.1016/j.enpol.2008.02.028

[11] Government of India, Ministry of Petroleum and Natural Gas. (2018). *National Policy on Biofuels - 2018*.

[12] Government of India, Ministry of Petroleum and Natural Gas. (2022). *National Policy on Biofuels - 2018 (Amended in 2022)*.

[13] Indian Sugar Mills Association. (2023). *Annual report 2022-23*. ISMA Publications.

[14] Indian Sugar Mills Association. (2024). *Annual report 2023-24*. ISMA Publications.

[15] Just, R. E., & Pope, R. D. (1979). Production function estimation and related risk considerations. *American Journal of Agricultural Economics*, *61*(2), 276–284. https://doi.org/10.2307/1239732

[16] Koizumi, T., & Ohga, K. (2007). Impacts of the Chinese bilevel tariff-rate quota system on the world raw and white sugar markets. *Journal of Agricultural & Food Industrial Organization*, *5*(1), Article 1158. https://doi.org/10.2202/1542-0485.1158

[17] Kumar, D., & Sharma, R. (2020). Techno-economic analysis of ethanol production from sugarcane in India. *Renewable and Sustainable Energy Reviews*, *134*, Article 110242. https://doi.org/10.1016/j.rser.2020.110242

[18] Markowitz, H. (1952). Portfolio selection. *The Journal of Finance*, *7*(1), 77–91. https://doi.org/10.2307/2975974

[19] Ministry of Consumer Affairs, Food & Public Distribution, Government of India. (2019). *Sugar season report 2018-19*. Department of Food and Public Distribution.

[20] Ministry of Consumer Affairs, Food & Public Distribution, Government of India. (2020). *Sugar season report 2019-20*. Department of Food and Public Distribution.

[21] Ministry of Consumer Affairs, Food & Public Distribution, Government of India. (2021). *Sugar season report 2020-21*. Department of Food and Public Distribution.

[22] Ministry of Consumer Affairs, Food & Public Distribution, Government of India. (2022). *Sugar season report 2021-22*. Department of Food and Public Distribution.

[23] Ministry of Consumer Affairs, Food & Public Distribution, Government of India. (2023). *Sugar season report 2022-23*. Department of Food and Public Distribution.

[24] Ministry of Consumer Affairs, Food & Public Distribution, Government of India. (2024). *Sugar season report 2023-24*. Department of Food and Public Distribution.

[25] Nair, S. R., & Goyal, A. (2014). Indian sugar industry: Sectoral analysis. *Agricultural Economics Research Review*, *27*(2), 205–216.

[26] Narayanan, S. (2014). Profits from participation in high value agriculture: Evidence of heterogeneous benefits in contract farming schemes in Southern India. *Food Policy*, *44*, 142–157. https://doi.org/10.1016/j.foodpol.2013.10.010

[27] National Federation of Cooperative Sugar Factories Limited. (2023). *Annual report 2022-23*. NFCSF.

[28] National Stock Exchange of India. (2018–2024). *Corporate filings database - Sugar industry*. https://www.nseindia.com

[29] Nguyen, T. L. T., & Gheewala, S. H. (2008). Life cycle assessment of fuel ethanol from cassava in Thailand. *The International Journal of Life Cycle Assessment*, *13*(2), 147–154. https://doi.org/10.1065/lca2007.08.351

[30] Rajagopal, D., Hochman, G., & Zilberman, D. (2018). The economics of ethanol production in India. *Energy Economics*, *71*, 292–301. https://doi.org/10.1016/j.eneco.2018.02.018

[31] Rao, C. H. H., & Mitra, A. (2019). Indian sugar industry: Towards a solution for chronic problems. *Economic and Political Weekly*, *54*(32), 55–62.

[32] Richards, V. D., & Laughlin, E. J. (1980). A cash conversion cycle approach to liquidity analysis. *Financial Management*, *9*(1), 32–38. https://doi.org/10.2307/3665310

[33] Securities and Exchange Board of India. (2018–2024). *Corporate governance and financial disclosures - Listed sugar companies*. https://www.sebi.gov.in

[34] Sharma, V. P., & Thaker, H. (2011). *Dynamics of sugarcane and sugar industry in Gujarat: Growth, productivity and structural changes* (Working Paper No. 2011-03-03). Indian Institute of Management Ahmedabad.

[35] Silalertruksa, T., & Gheewala, S. H. (2012). Environmental sustainability assessment of bio-ethanol production in Thailand. *Energy*, *43*(1), 586–591. https://doi.org/10.1016/j.energy.2012.05.002

[36] Singh, K. (2019). Impact of ethanol blending policy on sugarcane farmers in India: A case study of Maharashtra. *Indian Journal of Economics and Development*, *15*(3), 412–421.

[37] Taffler, R. J. (1983). The assessment of company solvency and performance using a statistical model. *Accounting and Business Research*, *13*(52), 295–308. https://doi.org/10.1080/00014788.1983.9729767

[38] Tyner, W. E., & Taheripour, F. (2008). Policy options for integrated energy and agricultural markets. *Review of Agricultural Economics*, *30*(3), 387–396. https://doi.org/10.1111/j.1467-9353.2008.00410.x

[39] Zarrilli, S. (2017). The emergence of biofuel markets and their impact on trade and development. In *Handbook on trade and development* (pp. 284–305). Edward Elgar Publishing. https://doi.org/10.4337/9781782546818.00023