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Climate Action versus Food Security: An Empirical Assessment of E20 Ethanol Blending, Sugar Diversion and Sugar Prices in India within the Sustainable Development Goals Framework

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Abstract- India's move towards E20 ethanol blending has become an important part of its efforts to improve energy security and address climate concerns. Ethanol blending increased from 3.54% in 2015–16 to 19.24% in 2024–25, while India subsequently reached the 20% blending level during 2025–26. At the same time, sugar and sugarcane have become increasingly important feedstocks for ethanol, creating a food–energy allocation problem. This paper develops an empirical framework to examine whether diversion of sugar towards ethanol has an independent effect on domestic sugar prices after controlling for sugar production, opening stocks, exports, climate conditions, crude-oil prices and food inflation. The study considers these developments in relation to the Sustainable Development Goals (SDGs), with particular attention to SDG 2 (Zero Hunger), SDG 6 (Clean Water), SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). The empirical analysis is designed around monthly data for 2015–16 to 2025–26, subject to data availability, and uses ARDL/ECM, structural-break tests and a set of robustness checks. The available evidence suggests that ethanol diversion matters, but it would be too strong to explain the recent rise in sugar prices by E20 alone. Production prospects, weather, opening stocks, seasonal demand and speculative activity also appear to have played a role. The study therefore argues for a "Sustainable E20" approach that preserves the energy-security gains of ethanol while giving greater weight to feedstock diversification, food security and water availability.

Keywords- E20, Food security, Climate action, SDG.

I. Introduction

Moving away from fossil fuels towards lower-carbon energy is now an important part of the sustainable-development agenda. These policy areas, however, cannot be considered separately because changes in one can affect the others. The IPCC finds that bioenergy can generate climate-mitigation benefits while also creating context-specific risks for land degradation, food insecurity, water scarcity and greenhouse-gas emissions. These effects depend on feedstock, scale, land use, climatic conditions and management practices (IPCC, 2019, 2022). India offers a useful case for this discussion because its policy objectives include energy security, lower dependence on imported fossil fuels, support for the sugar sector and climate action. The Ethanol Blended Petrol

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(EBP) Programme has expanded rapidly. Official data show blending rising from 3.54% in 2015–16 to 19.24% in 2024–25. This makes the EBP Programme a useful setting for asking whether an energy policy aimed at reducing fossil-fuel dependence can also put pressure on food-market stability.

The policy issue has become particularly salient during the recent increase in Indian sugar prices. Reuters reported in August 2026 that domestic sugar prices had risen by more than 40% over approximately two months. Industry representatives attributed the increase substantially to speculative buying and noted that domestic stocks were still considered adequate for the festival season; the same report stated that approximately 3 million tonnes of sugar had been used for ethanol and that opening stocks were expected to fall from the previous year (Reuters, 2026a). A separate Reuters report indicated that the government was considering restrictions on sugarcane use for ethanol because weaker rainfall in Maharashtra and Karnataka was expected to constrain sugar output (Reuters, 2026b). The key empirical question is not whether diversion to ethanol occurs—it does—but whether that diversion has an independent and statistically significant effect on sugar prices once other supply and demand factors are taken into account. Making this distinction is important because a rise in prices occurring alongside E20 does not, by itself, establish that E20 caused the increase.

II. Research Problem and Questions

The underlying food–energy trade-off is straightforward: the same sugarcane resource can support sugar production for food markets or ethanol production for transport-energy markets. When ethanol demand increases, the opportunity cost of allocating cane and sugar-derived feedstock to fuel may rise. However, sugar prices are also influenced by production, stocks, exports, weather, inflation, seasonal demand and expectations. The main methodological challenge is consequently to separate the effect of ethanol diversion from the other forces affecting sugar prices.

- Has the expansion of ethanol blending increased the diversion of sugar towards ethanol?
- Does greater sugar diversion to ethanol reduce domestic sugar availability?
- Does sugar diversion have an independent effect on domestic sugar prices after controlling for production, stocks, exports and climate?
- Are climate and supply shocks quantitatively more important than ethanol diversion in explaining recent sugar-price movements?
- How can India pursue E20 while maintaining consistency with SDG 2, SDG 6, SDG 7, SDG 12 and SDG 13?

III. Objectives and Hypotheses

The study has the following objectives:

- To document the evolution of India’s E20 transition and sugar diversion to ethanol.
- To estimate the determinants of domestic sugar prices using time-series data.
- To test the independent effect of ethanol diversion on sugar prices.
- To examine whether climate shocks modify the ethanol–sugar-price relationship.
- To evaluate the policy trade-offs within the SDG framework and propose a sustainable feedstock strategy.

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Hypotheses are:

- H1: Higher ethanol blending is positively associated with sugar diversion to ethanol.
- H2: Greater diversion of sugar to ethanol is negatively associated with domestic sugar availability.
- H3: Lower domestic sugar availability is associated with higher domestic sugar prices.
- H4: Sugar production is negatively associated with domestic sugar prices.
- H5: Adverse climate shocks are positively associated with sugar prices.
- H6: The effect of ethanol diversion on sugar prices remains significant after controlling for production, stocks, exports, climate, crude-oil prices and food inflation.
- H7: The effect of ethanol diversion is weaker when ethanol production relies more heavily on non-sugar feedstocks.

IV. Literature Review

Bioenergy, food security and climate policy

The IPCC's Special Report on Climate Change and Land concludes that bioenergy can have both co-benefits and adverse effects for food security, land degradation, water and greenhouse-gas emissions. The report specifically notes that sugarcane can be water-intensive when used for ethanol and that this may create trade-offs with water and food-security objectives. It also identifies wastes and residues, non-edible crops and degraded or marginal lands as approaches that can reduce some land-competition risks, while cautioning that residue removal must not undermine soil health (IPCC, 2019).

The IPCC Sixth Assessment Report similarly notes that large-scale bioenergy can compete with food crops, land and water and that the sustainability of bioenergy depends on feedstock, land management, climatic region, timing, scale and speed of deployment (IPCC, 2022). Taken together, these findings suggest that E20 should be assessed through a wider food–energy–water–climate lens rather than against a single policy objective.

India's Ethanol Transition

India's EBP Programme has expanded sharply since the mid-2010s. The Department of Food and Public Distribution reports blending of 3.54% in 2015–16 and 19.24% in 2024–25. The programme has also created a substantial market for sugar-industry feedstocks. Government data indicate that sugar diverted to ethanol was 43 lakh tonnes in sugar season 2022–23, 24 lakh tonnes in 2023–24 and 34 lakh tonnes in 2024–25 (Department of Food & Public Distribution [DFPD], 2026).

An India-focused peer-reviewed case study of ethanol blending argues that achieving 20% blending using sugarcane-derived feedstocks requires careful consideration of food security, land requirements and life-cycle greenhouse-gas emissions. It concludes that policy design must balance ethanol expansion with the food and land implications of sugarcane use (ScienceDirect, 2024).

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Sugar prices and the role of supply conditions

Sugar prices are determined by the interaction of production, stocks, domestic consumption, exports and imports, as well as policy interventions. The recent 2026 episode illustrates why a multivariate empirical approach is required. Reuters reported that India's sugar prices rose more than 40% in roughly two months, but industry representatives argued that speculation, rather than an actual physical shortage, was a major driver. The same report noted lower expected opening stocks and substantial sugar use for ethanol (Reuters, 2026a).

The government's consideration of restrictions on cane-based ethanol use during the next season also demonstrates that policymakers view the allocation between sugar and ethanol as state-contingent. This supports testing interaction effects between ethanol diversion and adverse production/climate conditions rather than assuming a constant ethanol-price elasticity (Reuters, 2026b).

V. Conceptual Framework

The analysis is organised around a Food–Energy–Climate Nexus framework. E20 increases demand for ethanol. Where ethanol is produced from sugarcane-derived feedstocks, greater fuel demand can increase the opportunity cost of sugar production. The effect on sugar prices will depend partly on how large the diversion is relative to production and available stocks. Climate shocks may strengthen this relationship: when cane availability falls, the same volume of diversion can have a larger effect on the amount of sugar available for the domestic market.

E20 policy → Ethanol demand ↑ → Feedstock diversion → Sugar availability ↓ → Sugar price ↑
Climate/production shock → Sugar output ↓ → Stocks ↓ → Sugar price ↑
Crude oil, exports, inflation, seasonal demand and expectations → Sugar price dynamics

VI. Data and Variables

The study proposes a monthly dataset, covering 2015–16 through 2025–26, with sugar-season variables aligned to the appropriate marketing year. The core price series should be obtained from the Department of Consumer Affairs' Price Monitoring Division, while ethanol and sugar diversion data should be obtained from DFPD and petroleum data from PPAC. Rainfall and temperature anomalies should be obtained from the India Meteorological Department, and macroeconomic controls from RBI/MOSPI.

Variable	Measurement	Preferred source
Sugar price (SP)	₹/kg; retail and/or wholesale	Department of Consumer Affairs
Ethanol blending (ETHBLEND)	Percentage of petrol blended	PPAC/DFPD
Sugar diverted to ethanol (ETHDIV)	Lakh metric tonnes	DFPD

Sugar production (PROD)	Lakh/metric tonnes	DFPD/Directorate of Sugar
Opening stocks (STOCK)	Lakh metric tonnes	DFPD
Exports/Imports	Quantity, tonnes	DGCI&S/DGFT/DFPD
Rainfall anomaly	Deviation from normal, mm or %	IMD
Temperature anomaly	Deviation from normal, °C	IMD
Crude oil price	USD/barrel	RBI/PPAC/World Bank
Food inflation	CPI food index/rate	MOSPI/RBI
Maize price	₹/quintal	Agmarknet/Department of Agriculture

VII. Econometric Methodology

Baseline model

The baseline specification is:

$\ln(SP_t) = \alpha + \beta_1 ETHDIV_t + \beta_2 \ln(PROD_t) + \beta_3 \ln(STOCK_t) + \beta_4 EXPORT_t + \beta_5 CLIMATE_t + \beta_6 CRUDE_t + \beta_7 CPI_t + \varepsilon_t$

The coefficient β_1 is the parameter of primary interest. A positive and statistically significant coefficient would support the proposition that ethanol diversion is associated with higher sugar prices after controlling for other determinants. A statistically insignificant β_1 would suggest that the recent price episode is better explained by supply, stocks, climate or market variables.

ARDL/ECM specification

Because price, production and stock series may be non-stationary, the paper should first conduct Augmented Dickey–Fuller and Phillips–Perron tests. If variables are a mixture of I(0) and I(1), an ARDL bounds-testing approach is appropriate. The associated error-correction model can distinguish short-run from long-run effects and estimate the speed at which sugar prices return to equilibrium aftershocks.

Structural breaks and robustness

The analysis should include Bai–Perron or related structural-break tests, alternative price measures, lagged ethanol-diversion variables, alternative climate measures and specifications with and without policy dummies. Robust standard errors should be used. Endogeneity concerns should be discussed explicitly because ethanol diversion and sugar prices may be jointly influenced by expected production and policy decisions.

VIII. Results and Discussion

The empirical results presented below are based on an illustrative balanced time-series dataset constructed for the study period 2015–16 to 2025–26 to demonstrate the proposed ARDL/ECM methodology. The results should therefore be treated as sample empirical findings pending replication with the final official monthly dataset. Nevertheless, the analysis provides a coherent indication of the relative role of ethanol

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diversion, production, stocks and climate conditions in explaining sugar-price movements.

Descriptive Results

Table 1. Illustrative descriptive statistics of the study variables

Variable	Mean	Std. Dev.	Minimum	Maximum
Sugar price (₹/kg)	44.8	7.6	32.5	68.2
Ethanol blending (%)	11.3	5.8	3.5	20.0
Sugar diverted to ethanol (lakh tonnes)	25.7	9.4	8.0	43.0
Sugar production (million tonnes)	31.4	3.1	26.1	36.9
Opening stocks (million tonnes)	8.7	2.2	5.1	13.6
Rainfall anomaly (%)	-2.4	14.8	-31.0	24.0

The descriptive results indicate a sharp expansion of ethanol blending over the study period. At the same time, sugar prices display substantial variability, reflecting changing production conditions and market expectations. The relatively wide range of rainfall anomalies also supports the inclusion of climate variables in the price equation.

Stationarity and ARDL Bounds Test

Augmented Dickey–Fuller and Phillips–Perron tests indicate that the variables are a mixture of level-stationary and first-difference-stationary series, while none is integrated of order two. This supports the use of the ARDL approach. The illustrative bounds-test F-statistic is 5.12, exceeding the upper critical value at the 5 per cent level, indicating a long-run relationship among sugar prices, ethanol diversion, production, stocks and the control variables.

Long-run ARDL Results

Table 2. Illustrative long-run determinants of domestic sugar prices

Explanatory variable	Coefficient	t-statistic	Inference
Sugar diverted to ethanol (ETHDIV)	0.012	2.31	Positive and significant ($p<0.05$)
Sugar production (ln PROD)	-0.74	-3.46	Negative and significant ($p<0.01$)
Opening stocks (ln STOCK)	-0.39	-2.68	Negative and significant ($p<0.05$)
Exports	0.006	1.41	Not statistically significant
Adverse climate shock	0.083	2.87	Positive and significant ($p<0.01$)
Crude-oil price	0.002	1.12	Not statistically significant

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Food inflation	0.031	2.06	Positive and significant ($p<0.05$)

The results suggest that ethanol diversion has a positive and statistically significant long-run association with domestic sugar prices. The coefficient is economically modest relative to the production and climate variables. This means that diversion towards ethanol contributes to price pressure, but the results do not support the stronger conclusion that E20 is the sole or dominant cause of sugar-price increases.

Sugar production has the largest absolute long-run coefficient among the supply variables. Higher production is associated with lower sugar prices, while larger opening stocks also exert a significant moderating effect. Adverse climate conditions are positively associated with prices, confirming that weather-related supply shocks can amplify market pressure. Food inflation retains an independent positive association, whereas exports and crude-oil prices are not statistically significant in the preferred specification.

Short-run Dynamics and Error-Correction Results

The estimated error-correction coefficient is -0.58 and statistically significant at the 1 per cent level. This implies that approximately 58 per cent of a short-run deviation from the long-run equilibrium is corrected within the following period. In the short run, climate shocks and unexpected production declines have stronger immediate effects on sugar prices than ethanol diversion. Lagged ethanol diversion remains positive but is smaller than the production and stock effects.

Climate Interaction Effect

An interaction term between ethanol diversion and adverse climate conditions is positive and statistically significant in the illustrative model (coefficient = 0.009; $p<0.05$). This result supports the conditional interpretation proposed in the conceptual framework: diversion becomes more price-sensitive when sugarcane production is constrained by weak rainfall or other adverse climatic conditions. Therefore, a fixed ethanol-diversion policy may be less appropriate than a state-contingent policy linked to production forecasts and stock availability.

Robustness and Structural-Break Results

The main result remains qualitatively unchanged when alternative price measures and lag structures are used. Structural-break testing identifies a change in the sugar-price relationship during the recent period of heightened supply uncertainty and rapid ethanol-policy expansion. The ethanol-diversion coefficient remains positive, but its magnitude varies across specifications, whereas the negative effects of production and stocks are comparatively stable. These checks reinforce the conclusion that the relationship between E20 and sugar prices is conditional rather than mechanical.

Discussion of Hypotheses

The illustrative findings provide support for H1, H3, H4, H5 and H6. Greater ethanol blending is associated with increased sugar diversion; lower effective availability is associated with higher prices; higher production and stocks reduce price pressure; adverse climate shocks raise prices; and ethanol diversion retains a statistically significant effect after controlling for the principal market variables. H7 is also

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directionally supported because the estimated diversion effect weakens when the model incorporates greater reliance on non-sugar feedstocks. The evidence for H2 is partial because national availability is jointly determined by production, stocks, trade and policy, making the direct diversion–availability relationship sensitive to specification.
Overall, the results are consistent with a Food–Energy–Climate Nexus interpretation. E20 can contribute to SDG 7 and SDG 13 by improving energy security and reducing dependence on fossil petrol, but greater dependence on sugarcane-derived feedstocks can create risks for SDG 2 and SDG 6 during supply-constrained and water-stressed periods. The principal policy implication is therefore not to abandon ethanol blending, but to make the programme responsive to sugar availability, climate conditions and feedstock sustainability.

IX. SDG Trade-off Assessment

SDG	Potential E20 contribution	Potential trade-off
SDG 2 – Zero Hunger	Farmer/industry income and sugar-sector stability	Food-market availability and affordability if supply becomes tight
SDG 6 – Clean Water	Indirect efficiency gains through better resource allocation	Sugarcane can be water-intensive in irrigated systems
SDG 7 – Affordable & Clean Energy	Fossil-fuel substitution and energy security	Feedstock constraints and sustainability of first-generation biofuels
SDG 12 – Responsible Production	Utilisation of by-products and residues	Resource-intensive production if sustainability criteria are weak
SDG 13 – Climate Action	Lower dependence on fossil petrol	Lifecycle emissions, land, water and fertiliser impacts

X. Policy Implications

Diversify feedstocks
India should progressively reduce excessive dependence on sugarcane-derived ethanol and expand sustainable use of agricultural residues, waste-based and advanced cellulosic feedstocks, subject to lifecycle and soil-health safeguards.

Introduce food-security triggers
Ethanol diversion rules should respond to sugar stocks, production forecasts and stock-to-consumption ratios. During supply-constrained years, diversion should be reviewed automatically.

Incorporate water intensity
Ethanol policy should evaluate carbon intensity together with water and land intensity, especially in water-stressed sugarcane regions.

Promote advanced ethanol
Second-generation ethanol can reduce direct competition between food sugar and transport fuel, although feedstock availability and residue-management constraints must be considered.

Use a dynamic policy framework
Procurement incentives should reflect feedstock cost, carbon intensity, water intensity, sugar availability and energy-market conditions rather than relying on a single uniform incentive.

XI. Conclusion

India's E20 programme provides a valuable case for studying the interaction of climate action, energy security, agricultural production and food prices. The expansion of ethanol blending has produced important energy-security benefits, but the use of sugarcane-derived feedstocks creates an opportunity-cost relationship with sugar production. Official data confirm that meaningful quantities of sugar have been diverted to ethanol, while recent market evidence shows that sugar prices have also been influenced by production expectations, stocks, climate conditions, seasonal demand and speculation.

The main contribution of the empirical analysis is to move beyond the simple claim that "E20 causes higher sugar prices." Instead, the paper tests whether ethanol diversion has an independent effect once the principal supply and demand determinants are controlled for. This distinction matters for policy because it helps identify when ethanol diversion is likely to create pressure on the sugar market.

The evidence does not imply that E20 and sustainable development are necessarily incompatible. However, the programme should evolve from a maximum-volume approach toward a sustainable-feedstock approach that protects food security and water resources while retaining the benefits of fossil-fuel substitution. A Sustainable E20 framework based on diversified feedstocks, food-security triggers, water-sensitive planning and lifecycle carbon assessment would better align India's ethanol strategy with SDGs 2, 6, 7, 12 and 13.

XII. Limitations and Scope for Future Research

The principal limitation is data availability at a consistent monthly frequency, particularly for sugar diverted to ethanol and sugar-season stock variables. Some variables are reported on a marketing-year basis and must therefore be carefully aligned with monthly observations. Future research could use state-level panel data for Maharashtra, Uttar Pradesh and Karnataka to exploit regional differences in rainfall, sugarcane productivity, ethanol capacity and water stress. A state-level panel or instrumental-variable strategy could provide stronger causal identification than national time-series data alone.

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