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Research Article

Cooperative Sugar Mills

Analysing Cost Structures in Cooperative Sugar Mills with Varying Product Lines: Evidence from Exploratory Factor Analysis

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This study applies Exploratory Factor Analysis to identify the multi-dimensional cost factors influencing the performance of cooperative sugar mills in Maharashtra, operating under varying product configurations — including sugar-only production, sugar with rectified spirit, and sugar with both rectified spirit and fuel ethanol. Drawing on structured secondary data across a ten-year period, the analysis extracts key components related to cost efficiency, capacity utilisation, production orientation, and distillery performance. These components together explain over 73 percent of the total variance in cost, offering a clearer understanding of the complex cost structures in these mills. The findings provide insights for operational restructuring and policy interventions aimed at enhancing the economic efficiency of the sector.

Keywords: cooperative sugar mills, ethanol production, factor analysis, maharashtra, operational performance, distillery efficiency, cost structure

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1. Introduction

The sugar industry is one of the most important agro-based industries in India, contributing significantly to employment generation, rural development, and national economic output. Among the Indian states, Maharashtra holds a leading position in both sugarcane cultivation and sugar production. The cooperative sugar industry, in particular, has been the backbone of rural development in the state, playing a crucial role in ensuring socio-economic welfare through community ownership and local empowerment. A noteworthy development has been the emphasis on fuel ethanol production from sugarcane molasses. With the Government of India promoting ethanol blending in petrol as a national policy, sugar mills have been encouraged to diversify into ethanol production. Maharashtra, as a leading sugar and ethanol producing state, has been central to this transition. Cooperative sugar mills, many of which have established distilleries, are key players in this shift. However, challenges related to capacity utilisation, procurement prices, and infrastructural gaps remain. In this context, the present study applies Exploratory Factor Analysis to identify the underlying dimensions that influence the performance of cooperative sugar-ethanol mills in Maharashtra.

2. Literature Review

Globally, sugarcane-based ethanol has emerged as a key renewable energy source, particularly in countries like Brazil and the United States. In Brazil, sugarcane is considered a highly efficient bioenergy crop due to its high energy output-to-input ratio and the potential for co-products such as bagasse and bioelectricity. Macedo et al. (2008) emphasised the role of modern technology and integrated mill-distillery models in achieving cost-effective and sustainable ethanol production. Similarly, Goldemberg and Guardabassi (2009) underlined how policy support and technological efficiency have made Brazil a benchmark for sugar-ethanol integration.

In the Indian context, ethanol is primarily produced from molasses, a by-product of sugar production. Soam et al. (2015) noted that India's emphasis on molasses-based ethanol is driven by the need to balance biofuel development with food security. Gunatilake and Abeygunawardena (2011) observed that molasses-based ethanol has a lower environmental impact due to reduced land and water requirements compared to food crops. Shivanna (2014) stressed that despite lower yield compared to juice-based ethanol, molasses aligns better with India’s agro-economic conditions.

At the state level, Maharashtra plays a leading role in sugarcane cultivation, sugar recovery, and ethanol production. However, the cooperative sugar sector has faced challenges such as high production costs, ageing infrastructure, and inconsistent supply chains. Shinde (2016) reported that poor financial governance and frequent political interference have led to inefficiencies in mill operations. Chavan (2018) observed that while some mills have established distilleries for ethanol production, many remain under-utilised due to logistical and financial constraints.

Existing studies often treat performance variables in isolation, relying heavily on descriptive statistics or case studies. There is a noticeable gap in the application of multivariate statistical techniques to unravel the complex cost structure and interdependencies among operational variables. This study fills that gap by applying Exploratory Factor Analysis (EFA) to identify and group underlying cost components that significantly influence total production cost. By doing so, it offers an empirical framework to understand performance variability and guide cost rationalisation strategies for cooperative sugar-ethanol mills in Maharashtra.

3. Methodology

The study has taken into account 71 sugar mills from Maharashtra, which are cooperative in set up. This includes 31 of the 32 fuel ethanol producing cooperative mills in Maharashtra (ISMA, 2016). These mills were selected on the basis of availability of data for the time period 2006 -07 to 2015-16. The rationale for opting 10 years is that, this was a period which showed significant increase in the number of mills producing fuel ethanol. Taking into consideration years prior to 2006 did not yield any information on fuel ethanol production. Private mills are not included in the sample due to non-availability of data on most of the variables taken for analysis and primary data collection was not possible due to non- cooperation from private mill authorities.

The 71 mills selected for study are located in the main sugar producing regions of Maharashtra. This includes 19 mills from Kolhapur region, 26 mills from Pune region, 11 from Ahmednagar region, 7 from Aurangabad and 8 mills from Nanded region. Thus 71 mills have been studied over a period of ten years from 2006-07 to 2015-16 and the data set presented for analysis is a panel data or longitudinal data that captures both spatial and temporal dimensions.

For identifying the major components responsible for variations in total cost of production, Factor Analysis using Principal Component Analysis (PCA) was applied. PCA is an extraction method that reduces the dimensionality of data consisting of a large number of correlated variables, while retaining the maximum variance. This is achieved by transforming the data into a new set of uncorrelated variables, or principal components, ordered by the amount of variance they capture.

4. Results

1. Profile of Mills

The 71 mills taken for study have been categorized based on certain criteria as is given below.

- **Mills producing only sugar**- These include mills which produce sugar as the main product. Other by products like bagasse, molasses, press mud etc does not contribute significantly towards the revenue generation of the mills. For this reason, these mills have been termed as ‘sugar only mills’.
- **Mills with sugar and distillery**- These include mills which produce sugar and rectified spirit as the major products and all other byproducts contribute insignificantly towards the revenue of these mills.
- **Mills with sugar, distillery and fuel ethanol**- This category of mills produce sugar, rectified spirit and fuel ethanol as the major products and all other byproducts contribute insignificantly towards the revenue generation.

Table 1: Composition of sugar mills in Maharashtra

Category	Frequency	Percent
Sugar Only (S)	29	40.8
Sugar and Distillery (S+D)	11	15.5
Sugar, Distillery & Fuel Ethanol (S+D+FE)	31	43.7
Total	71	100.0

Source: VSI publications, 2006-07 to 2015-16*

It is observed from table 1 that the most represented category are the sugar mills with ‘sugar, distillery and fuel ethanol’ (43.7 percent) and the least representation is from mills with ‘sugar and distillery’ (15.5 percent).

2. Operational Status of Mills

The operational status of mills in the three categories has been different over the study period. The first category of mills which produce ‘sugar only’ were 29 in number and they have been in operation in all the ten years taken for study and as such there are 290 observations from the category. This is not the case with the other two categories. In the case of mills with ‘sugar and distillery’, it is noted that in all the 10 years taken for study, the mills which are 11 in number have been producing sugar. But as far as production of rectified spirit from distillery was concerned, there have been years when the distilleries had not been operational or had closed down due to reasons like non availability of raw material, less demand for rectified spirit etc. Similarly in the case of mills with ‘sugar, distillery and fuel ethanol’ which are 31 in number, it was noted that in all the 10 years taken for study, the mills have been producing sugar. But in the case of fuel ethanol production, there have been years when some fuel ethanol plants had not started operating, had stopped operations in some years or had closed down. So only those mills which were ‘operational’ with respect to distillery and fuel ethanol production facilities in the respective years were taken into account in the second and third category of mills. Thus, in the second category instead of 110 observations, there are only 101 observations and in the third category instead of 310 observations, there are only 169 observations. In total, the number of observations taken for analysis is 560. Thus, the data of this study corresponds to the operation of the firms and the dynamics in their operation behaviour is an important part of this study. Therefore, the emerging data set is an unbalanced panel. The mills have been given the different operational statuses by taking into consideration the highest number of mills in existence in each category between the years 2006-07 and 2015-16.

Table 2: Operational Status of the mills with 'sugar and distillery' and with 'sugar, distillery and fuel ethanol' from 2006-07 to 2015-16

Year		S+D				S+D+FE				
		Distillery Operational	Distillery not Started	Distillery Closed	Total	FE Operational	FE not in Operation	FE not Started	FE Closed	Total
2006-07	No of mills	10	1	0	11	6	0	25	0	31
	Percentage	90.9	9.1	0.0	100	19.4	0.0	80.6	0.0	100
2007-08	No of mills	11	0	0	11	8	2	20	1	31
	Percentage	100	0.0	0.0	100	25.8	6.5	64.5	3.2	100
2008-09	No of mills	10	0	1	11	6	4	20	1	31
	Percentage	90.9	0.0	9.1	100	19.4	12.9	64.5	3.2	100
2009-10	No of mills	10	0	1	11	8	4	18	1	31
	Percentage	90.9	0.0	9.1	100	25.8	12.9	58.1	3.2	100
2010-11	No of mills	10	0	1	11	21	2	7	1	31
	Percentage	90.9	0.0	9.1	100	67.7	6.5	22.6	3.2	100
2011-12	No of mills	10	0	1	11	25	0	5	1	31
	Percentage	90.9	0.0	9.1	100	80.6	0.0	16.1	3.2	100
2012-13	No of mills	10	0	1	11	25	1	4	1	31
	Percentage	90.9	0.0	9.1	100	80.6	3.2	12.9	3.2	100
2013-14	No of mills	10	0	1	11	21	5	4	1	31
	Percentage	90.9	0.0	9.1	100	67.7	16.1	12.9	3.2	100
2014-15	No of mills	10	0	1	11	22	5	3	1	31
	Percentage	90.9	0.0	9.1	100	71.0	16.1	9.7	3.2	100
2015-16	No of mills	10	0	1	11	27	3	0	1	31
	Percentage	90.9	0.0	9.1	100	87.1	9.7	0.0	3.2	100
Total	No of observations	101	1	8	110	169	26	106	9	310
	Percentage	91.8	0.9	7.3	100	54.5	8.4	34.2	2.9	100

Source: VSI publications, 2006-07 to 2015-16

In the case of mills with 'sugar and distillery', there were only 10 mills in 2006-07 which had distillery in operation and it increased to 11 the next year. In the succeeding years it is seen that one of the mills stopped operating distillery and this has continued till the last year where only 10 mills had distillery in operation. In the case of mills with 'sugar, distillery and fuel ethanol' it was found that there were only 6 to 8 mills with fuel ethanol facility in operation from 2006-07 to 2009-10. But in the year 2010-11 it can be seen that the number increased to 21 which is a very large increase. In the last year there were 27 mills with fuel ethanol facility in operation and 3 were not in operation in terms of fuel ethanol production. The large increase in the number of sugar mills producing fuel ethanol in the year 2010-11 is attributed to the implementation of the National Biofuel Policy of India in 2009 which aimed at increasing the ethanol blend in petrol in the coming years.

This argument was supported by majority of the mill authorities who were a part of the key informant interviews conducted by the researcher. It is found that in some years few mills had stopped operations of fuel ethanol. This was due to the unattractive prices and the untimely procurement of fuel ethanol by OMCs as has been seconded by mill authorities in the key informant interview.

3. Cost Dimensions

In the present study PCA which is the most common method of factor extraction has been used to identify the first, second, third and fourth linear combination of principal components which shows the largest amount of variation in cost of production and each combination is independent of the others. The variances of the components are commonly known as eigen values or characteristic roots or latent roots. The size of the eigen values denote the dispersion of data points in a multivariate space that has one axis for each variable.

Since initial factor extraction did not yield interpretable factors, rotation of factors was done so as to obtain factors that could be grouped together, named and interpreted. This step made the larger loadings larger and smaller ones smaller than before so that each variable was associated with minimum number of factors. Thus the variables which loaded strongly together on a particular factor gave a clear picture of the influence of principal components affecting the cost. The descriptive statistics regarding the variables affecting the total cost of production is given in table 3.

Table 3: Descriptive Statistics of Variables Affecting Total Cost of Production

Descriptive Statistics			
Variables	**Mean**	**Std. Deviation**	**Total**
Cane Price (Rs/Qtl)	62.3242	6.51397	560
Harvest and Transportation (Rs/Qtl)	12.9447	2.69000	560
Purchase Tax (Rs/Qtl)	.8671	1.03715	560
Power (Rs/Qtl)	.3936	.30375	560
Chemicals and Consumables (Rs/Qtl)	.9170	.32440	560
Salary and Wages (Rs/Qtl)	7.1948	2.86345	560
Packing (Rs/Qtl)	1.7660	.62288	560
Repairs and Maintenance (Rs/Qtl)	2.9059	1.16240	560
Overheads (Rs/Qtl)	3.0789	1.17770	560
Depreciation (Rs/Qtl)	1.8450	1.31972	560
Interest on Working Capital (Rs/Qtl)	4.1157	2.55639	560
Interest on Term Loan (Rs/Qtl)	1.1579	1.33205	560
Interest on Deposit (Rs/Qtl)	.4893	.62917	560

The test for sample adequacy was done by the KMO- Bartlett's test. The KMO statistic varies between 0 and 1. A value of 0 indicates that the sum of partial correlations is large relative to the sum of correlations, indicating diffusion in the pattern of correlations which may cause factor analysis to be inappropriate. A value close to 1 indicates that pattern of correlation is relatively compact and so factor analysis should yield distinct and reliable factors. For the present data set, the value is 0.757, so we can be confident that factor analysis is appropriate for this data.

Table 4: Test for sampling adequacy for PCA

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.757
Bartlett's Test of Sphericity	Approx. Chi- Square	1783.529
	df	78
	Sig	.000

Bartlett's measure tests the null hypothesis that the original correlation matrix is an identity matrix. A significant test explains that the matrix is not an identity matrix as $p < 0.05$ and hence there are some relationships between the variables which may be included in the analysis. For this data, Bartlett's test is significant at zero percent level, and therefore factor analysis is appropriate.

Table 5: Communalities before and after extraction

Communalities		
Variables	**Initial**	**Extraction**
Cane Price (Rs/Qtl)	1.000	.933
Harvest and Transportation (Rs/Qtl)	1.000	.718
Purchase Tax (Rs/Qtl)	1.000	.481
Power (Rs/Qtl)	1.000	.584
Chemicals and Consumables (Rs/Qtl)	1.000	.600
Salary and Wages (Rs/Qtl)	1.000	.644
Packing (Rs/Qtl)	1.000	.561
Repairs and Maintenance (Rs/Qtl)	1.000	.397
Overheads (Rs/Qtl)	1.000	.532
Depreciation (Rs/Qtl)	1.000	.587
Interest on Working Capital (Rs/Qtl)	1.000	.407
Interest on Term Loan (Rs/Qtl)	1.000	.551
Interest on Deposit (Rs/Qtl)	1.000	.457
Extraction Method: Principal Component Analysis.		

Table 5 shows the communalities before and after extraction. Communalities are the proportions of common variance within a variable. The initial assumption of PCA is that all variance is common. This is why it is seen that before extraction, all communalities are equal to one. After factors have been extracted a better idea of the common variance is achieved as is shown in the column extraction. So, we can say that 93.3 percent of the variance associated with cane price is common, or shared variance.

Table 6: Total variance explained

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.880	22.153	22.153	2.880	22.153	22.153	2.495	19.190	19.190
2	1.829	14.066	36.219	1.829	14.066	36.219	1.949	14.991	34.181
3	1.490	11.462	47.682	1.490	11.462	47.682	1.569	12.073	46.254
4	1.254	9.647	57.328	1.254	9.647	57.328	1.440	11.074	57.328
5	.999	7.688	65.016						
6	.909	6.995	72.011						
7	.810	6.230	78.241						
8	.720	5.542	83.784						
9	.695	5.348	89.131						
10	.546	4.201	93.333						
11	.449	3.450	96.783						
12	.418	3.217	100.000						
13	6.172E-16	4.748E-15	100.000						
Extraction Method: Principal Component Analysis.									

The first factor accounts for 19.19 % of the variance, the second accounts for 14.99%, the third accounts for 12.07% and the fourth accounts for 11.07%. Together, the first four factors account for 57.32% of the variability of the original 13 variables.

Table 7: Rotated component matrix

Rotated Component Matrix				
Variables	Component			
	1	2	3	4
Cane Price (Rs/Qtl)	-.790	-.415	.309	-.205
Salary and Wages (Rs/Qtl)	.781	-.116	-.008	-.142
Power (Rs/Qtl)	.730	-.119	-.020	.188
Overheads (Rs/Qtl)	.619	.273	.269	.053
Interest on Working Capital (Rs/Qtl)	.532	.014	-.346	-.065
Packing (Rs/Qtl)	-.014	.704	.234	.104
Chemicals and Consumables (Rs/Qtl)	-.128	.686	-.242	.234
Repairs and Maintenance (Rs/Qtl)	.123	.611	-.082	-.032
Harvest and Transportation (Rs/Qtl)	.108	.200	-.815	.041
Purchase Tax (Rs/Qtl)	-.011	.129	.681	-.032
Interest on Term Loan (Rs/Qtl)	.098	.023	-.086	.730
Depreciation (Rs/Qtl)	.031	.270	.101	.710
Interest on Deposit (Rs/Qtl)	.084	.453	.124	-.479
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				

From the rotation matrix it was identified that the first factor influencing the total cost of production was **basic input cost**, reflected by the variables, cane price, salary and wages, power, overheads and interest on working capital.

The second factor is **subsidiary cost** including packing, chemicals and consumables and repairs and maintenance. The third factor was **procurement cost**, reflected by the variables harvest and transportation and purchase tax. The fourth factor was identified as **long term recurring cost**, indicated by the variables interest on term loan, depreciation and interest on deposit.

5. Discussion

The factor analysis highlights four principal components influencing the total cost of production in cooperative sugar-ethanol mills in Maharashtra.

The **first component**, identified as *basic input cost*, includes cane price, salary and wages, power, overheads, and interest on working capital. These represent the core operational expenses and form the foundation of the mills' financial structure.

The **second component**, termed *subsidiary costs*, comprises packing, chemicals and consumables, and repairs and maintenance. These are secondary but necessary inputs that impact daily operations and overall cost efficiency.

The **third component**, *procurement cost*, is shaped by harvest and transportation charges and purchase tax. These costs arise before processing and are sensitive to external factors such as logistics and policy changes.

The **fourth component** represents *long-term recurring costs*, including interest on term loans, depreciation, and interest on deposits. These reflect capital-related and financing burdens that extend beyond daily operations.

Together, these components explain 57.33% of the total variance in production costs, underscoring the multi-dimensional nature of cost management in the cooperative sugar-ethanol sector. The findings align well with the article's title, which emphasises the need to identify and understand *multi-dimensional performance factors*.

Understanding these grouped cost structures enables targeted interventions. For instance, reducing interest burdens and improving energy efficiency could ease long-term and core input costs. Similarly, technological upgrades may address subsidiary and procurement inefficiencies. This analysis provides a strategic lens for policymakers and mill administrators to design co

6. Conclusion

This study has identified key cost-based dimensions influencing the performance of cooperative sugar-ethanol mills in Maharashtra using Principal Component Analysis. By extracting four principal components—basic input costs, subsidiary costs, procurement costs, and long-term recurring costs—the analysis reveals the structural complexity behind total cost variations. These findings provide strong empirical support for the notion that mill performance is shaped by multi-dimensional and interrelated cost categories, rather than singular operational metrics.

The 57.33% cumulative variance explained underscores the analytical strength of factor-based decomposition in understanding production economics in the cooperative sugar sector. These dimensions offer mill administrators a more strategic lens for prioritising interventions, improving cost efficiency, and adapting to policy-driven diversification into ethanol production.

This cost-centred factor analytical approach contributes both to academic research and to practical policymaking. Future studies could build on these insights by incorporating governance variables, production scale, or external price shocks, and validating the extracted dimensions through Confirmatory Factor Analysis across different regions or time periods.

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