Measuring the Impact of Inventory and Marketing on Production Smoothening in a Utility Sector: A Panel Data Approach

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Abstract. Utility sector is the foundation of economic growth that ensures energy security and industrial productivity along with influencing the living standards especially for the developing countries. The present study critically examines the progressing landscape of India's utility sector, focusing on demand side drifts, executive challenges, financial performances and technological improvements. The study uses extensive panel data of 26 major firms of the utility sector listed in Bombay Stock Exchange (BSE) sectoral indices over the period of 10 years (2013-2023). The panel data analysis includes multiple linear regression modelling, random effect analysis and fixed effect regression models capture the heterogeneity in the data. The regression model indicates that change in cost of goods sold (proxy variable of demand), marketing expenses, profit before interest and tax (PBIT) and inventories are significantly impacting the change in cost of production (proxy variable for production). Between ordinary least square (OLS) and random effect, Breusch pagan test concluded that random effect is better approach which shows time invariability. After that Hausman test confirms that there is temporal dynamism present in data and hence the fixed effect prevails. The study provides valuable insights for optimizing production smoothening and hence the operational efficiency based on financial performance.

Keywords: Utility sector, profits, marketing, inventory, production, panel data analysis, India

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1. Introduction

Utility sector serves a critical role in economic development, energy, and security of every economy (Vu and Gurtoo, 2014). As a provider of essential services like electricity, water and gas, the sector vitally impacts the GDP growth, industrial productivity and overall living standards. The sector contributes to poverty eradication by fulfilling basic human needs that further lead to economic growth. Increasing population even further leading to increased demand for the products of this industry (Thakur and Chakraborty, 2016). To sustain the needs energy and electricity demand will increase (Tiewsoh et al., 2019). With a population exceeding 1.4 billion and a growing energy demand, the Indian utility sector is facing challenges such as climate variability, infrastructure constraints and regulations (Chaturvedi et al., 2012). The competitive electricity market has heightened the need for technical efficiency in the utility sector (Sarica and Jain, 2007).

Demand supply mismatch is the common phenomenon that is visible in utility sector (Gupta & Saxena, 2023). Demand for utility sector exceeds the available supply leading to shortage of these services. Rapid urbanization, economic growth, population growth, aging infrastructure and technological advancements are some of the key issues that lead to this mismatch (Gupta & Saxena, 2020). As a result, there are power outages, water shortages, economic losses and social rest in the economy. Investment in infrastructure development, demand side management, renewable energy integration and regulatory reforms are some of the solutions that can resolve this problem. A demand supply mismatch in the utility sector, particularly in electricity, affects both financial health and operational stability of the firms. Mismatches strain the entire value chain from generation to distribution resulting in payment delays, increased dues and a cycle of financial distress that can hinder future investments and sectoral growth persistent demand supply mismatches undermine the sector's ability to deliver reliable, affordable and sustainable services, necessitating careful planning, policy intervention and investment to restore balance and ensure long term stability. Demand and supply management in the utility sector involves strategies to manage electricity demand and supply, integrated supply and supply chain balancing are some of the strategies (Goel et al., 2020)

Before 1990s, government owns various agencies of the utility sector facing severe issues of sectoral efficiency and effectiveness (Dubash & Rajan, 2001; Williams & Ghanadan, 2006). As infrastructure services significantly contribute to GDP, these inefficacies affected national income growth (Estache et al., 2002). To enhance efficiency, the privatization and regulatory changes were introduced in later years which yielded mixed results. Evaluations such as difference-in-difference (DID) and stochastic frontier analysis (SFA) were used to measure reform effects that indicated efficiency gains were not uniform across states and sectors. Studies suggested that strategic implementation are required to improve service quality along with maintaining affordability and financial stability (Verma et al., 2020). During the third quarter of 2023 the GDP contribution of utility sector reached an all-time high of 976.86 INR billion while it increased to 1038.05 INR billion in the second quarter of 2024.

2. Literature Review

The utility sector plays a leading role in growth and development of an economy. As India is evolving towards a developed country per-capita income levels, based on its climate conditions and on fuel preferences that may linger from the present and vestiges of its development, the Indian utility sector is largely evolving (Chaturvedi et al., 2012). As the economy is projected to grow at 8-9% per annum, the demand is likely to grow significantly to satisfy rapid urbanization and increasing living standard demands (Garg, 2012). But there was an absence of long-term equilibrium relationship between per capita energy consumption and per capita GDP (Singh and Vashishtha, 2020). The growth rate had touched the six years low in the first financial quarter of April-June 2020. The manufacturing, public administration and utilities have positive dependability on growth (Sabitha, 2020). The GDP share of the utility sector is declining along with the growth in the employment share (M.Vu & Gurtoo, 2014).

The electricity sector has transitioned from conventional, carbon-intensive systems to dynamic and renewable-integrated frameworks. Only Supply driven approach is not enough to address the problems of the electricity sector (Balasubramanian & Balchandra, 2021). Due to low electrification rate and to the rationing of power supply, there is shortage of electricity (Jain et al., 2019). Demand side management has an important role in maintaining the balance between supply and demand (Balijepalli et al., 2011). To solve the problem of power and energy shortages, demand supply management (DSM) is the new aspect of the Indian power industry. Indian utilities are now focusing on load management (Sinha et al., 2011). By 2030, with GDP and population growth driving the trend, electricity demand is projected to increase two to threefold (Tiewsoh et al., 2019). Demand forecasting models suggested significant elasticity between electricity consumption and income levels. Although some studies revealed that state-owned utilities (SEOU) exhibit suboptimal performance and scale inefficiencies (Thakur et al., 2006). The inefficiencies in state-owned generation utilities is measured using data envelopment analysis (DEA) which concluded that cost reductions of up to 25% could be achieved without even reducing output (Jain et al., 2010).

With Indian State-Owned Electric Utilities (SEOUs), financial turmoil remains a major issue incurring losses exceeding $6.25 billion (Ghosh et al., 2021). Trends in gross and net non-performing assets of Indian banks focusing on Indian energy sector concluded that the level of NPAs of energy sector is alarming and the expected investment requirements in this sector is very high (Kumar et al., 2023). Econometrics modelling such as Panel regression analysed the impact of tariff inadequacies, poor governance and inefficiencies on financial performance (Gulati, 2011). In addition, corruption has negatively impacted government revenue and consumer trust (Chohan & Awad, 2020). To avoid financial burden of extra power purchase cost, the firms in the utility sector are now restoring to load shedding (Gulati, 2011).

According to government it is essential to enhance the installed capacity of Renewable Energy (RE), as still 75% of the electricity is still generated by coal-fired power plants (Srikanth, 2018). By 2050, renewable based power system could be more cost effective than current coal dominated system through which greenhouse gases has been emitted (Gulagi et al., 2022). To achieve grid stability, flexible energy resources such as demand resource programmes, energy storage and load management are important (Abhyankar, 2021). To further enhance sustainability, the integration of smart grid technologies and green supply chain management are required, with econometric modelling playing a vital role in optimizing renewable energy investments (Muduli et al., 2013).

Gupta & Saxena (2020) used change in cost of production (COP) as a proxy variable for production smoothening and operational efficiency that is influenced by the variables such as COGS, profits, marketing and inventories and reflects the sector. Change in cost of goods sold (COGS) reflects the direct demand for the utility products and serves as a proxy for output required to meet market needs (Sabitha, 2020). Studies have found a unidirectional causality between per capita GDP and per capita energy consumption and a Granger-causal relationship between energy consumption and energy growth (Tiwari et al., 2021; Khanna & Rao, 2009). Marketing expenses (Mkt) can influence inventory levels and supply chain dynamics. However, excessive marketing may lead to inventory buildup and supply chain disruptions if not matched by demand (Gupta & Saxena, 2020a; Muduli et al., 2013). Marketing expenses often have limited direct impact on profits in the utility sector, but may affect cost structures (Srivastava & Kathuria, 2020). Profits (PBIT) are a key measure of operational efficiency and financial health. Declining profits may indicate rising production costs or inefficiencies (Ghosh et al., 2021). Persistent low profits can signal financial distress, often linked to non-performing assets (NPAs) in state-owned utilities (Kumar et al., 2023). Inventories (Inv) act as a buffer against demand-supply mismatches but excessive inventories can tie up capital and increase costs (Muduli et al., 2013).

To attain financial stability and efficiency, regulatory interventions such as universal metering, cross-subsidy reductions and improved resource planning are necessary (Rajkumari, 2020). There is a need to handle the distribution segment in a more efficient way and for that third generational reforms are required. It has been observed that the Electricity Amendment Bill 2014 introduced competition in the Indian retail market by separating distribution business from supply business (Agrawal et.al, 2017). Policy evaluations utilizing techniques such as structural equation modelling (SEM) and instrumental variable regression indicate that regulatory changes can improve efficiency while also lowering financial burdens. Improvement in utility level governance should be focused in the future reforms (Bhatt and Singh, 2021). Operational and financial performance of the utilities can also be improved through employing effective corporate governance (Srivastava & Kathuria, 2020).

Panel data allows for analysis of both cross-sectional (across firms) and time series (over years) variability, capturing heterogeneity in the sector (Verma et al., 2020). Suitable when entity-specific effects are uncorrelated with independent variables. Breusch pagan test is used to determine appropriateness (Wooldridge, 2010). When used, unobserved heterogeneity is correlated with independent variables, thus using Hausman test helps choose between fixed and random effects (Baltagi, 2008). Studies have shown that fixed effect often prevails in utility sector analyses due to temporal dynamism and entity specific factors (Jain et al., 2010; Gulati, 2011).

The rest of the study is organized as follows. Section 3 discusses the objective methodology. The results and discussions are explained in section 4.

3. Research Methodology

The purpose of this study is to analyze how the variability exists in production variability can be determined when studies as a function of demand and the variables that are impacting the production like inventory and marketing. For this, the study addresses the following objectives:

To examine how cost of goods produced is affected by marketing expenses, cost of goods sold, profit before interest and tax and inventories in the Indian Utility sector. The relationships between these variables are quantified using panel data regression techniques. Secondly, investigating whether variations in the cost of production are primarily driven by differences across firms (entities) or time. Fixed effect and random effect models are used to capture and analyze heterogeneity in the panel data. Then, the study also highlights the inefficiencies in the public sector enterprises and explores the financial distress causes by non-performing assets (NPAs). The study identifies the need for state-intervention and policy reforms to improve efficiency and financial performance. The study identifies the role of marketing and inventory management on supply chain dynamics.

The steps to carry out research, including data collection and detailed analysis, are explained in this section. Validity of items are ensured through extensive literature review and variables are being verified to ensure content validity. After finalization of the variables the large observations are collected as follows. Major firms listed in the Bombay Stock Exchange (BSE) sectoral indices that represent and reflect the utility sector are being taken. The performance of the firms shows how movement in that specific sector is impacted by various factors such as trading frequency, market capitalization etc. The utility sectors of India are taken into consideration due to their independent nature. As of 2022, the contribution of utility sector in India's GDP was valued at over 786 billion India rupees. BSE sectoral indices are used to study the sector's performance. BSE sectoral listed firms are selected from these sectors. Last 10 years data of 26 firms of utility sector has been taken (from 2013 to 2023) using Prowess® Database. The study uses unbalanced panel data collected over a period of 10 years. The variables chosen to analyse the effects are change in cost of goods sold (COGS) to measure demand, cost of production (COP), marketing expenses (Mkt), PBIT and inventory (Inv). The cost of production denotes the manufacturing cost that arises during an accounting period whereas cost of goods sold is the production cost of goods that are sold during that period. If the change in production is negative and change in demand is positive then production cannot match up the demand, hence may lead to supply chain disruption. The study also addresses the impact of marketing expenses on supply chain disturbances. Marketing expenses often result in inventory-related problems and have very little impact on profit. The effect of profits on cost of goods has been also taken into consideration. If the profits are decreased for an entity, it implies that its production cost has increased.

After identifying the objectives and performing an extensive literature review on it. Data has been arranged using MS- Excel, in which rows contain the firms and columns contain the variables that are taken into consideration. A linear regression model has been set up, where cost of production has been taken as a dependent variable and cost of goods sold, marketing expenses, PBIT and inventories are taken as independent variables. The equation is as follows:

$$COP = \beta_0 + \beta_1 * COGS + \beta_2 * Mkt + \beta_3 * PBIT + \beta_4 * Inv + \varepsilon \tag{1}$$

STATA-15 is used to run the model. Model diagnose testing is also being performed. It has been found that the Gauss Markov assumptions of the linear regression model are satisfied. Thus, having no issues of autocorrelation, heteroscedasticity and multicollinearity.

The model fit test is represented in Table1, the test considers that independent variables when together are not explaining the variability that exists in the change in cost of production as the null hypothesis which is rejected as the p value of the F statistics appears to be 0.0000. Adjusted R- Squared value is given as 0.9612.

Table 1: Model Fit Test statistics of linear regression

Source	SS	df	MS	Number of obs.	=	163
Model	2.7281E+12	4	6.8201E+11	F (4,158)	=	1003.41
Residual	1.0739E+11	158	67691952	Prob>F	=	0.0000
Total	2.8350E+12	162	1.7503E+10	R-squared	=	0.9621
				Adj R-squared	=	0.9612
				Root MSE	=	26071

(Source: Author's calculation)

The coefficient of variables along with their standard error are listed in Table 2. All the independent variables are significant at 0.5% level of significance.

Table 2: Coefficient and Standard error with the p values

Cost of Production	Coefficient	Std. Error	t	P>|t|	[95% Conf. Interval]	
Cost of goods sold	-0.945028	0.0255791	-3.69	0.000	-0.1450239	-0.0439817
Marketing expenses	39.36089	2.830864	13.9	0.000	33.76968	44.95211
PBIT	0.4008218	0.0627849	6.38	0.000	0.2768158	0.5248278
Inventories	4.655743	0.329981	14.11	0.000	4.004	5.307486
_cons	-7481.103	2504.554	-2.99	0.000	-12427.83	-2534.379

(Source: Author's calculation)

After performing the regression analysis, we have performed random effect and fixed effect regression to check whether the variables change with respect to entity or with respect to time or otherwise to check the heterogeneity among the data. First, random effect analysis has been performed, and the results are shown in Table 3. The random effect model assumes that the unobserved individual effect is random and uncorrelated with the independent variables. The study considers the random effect equation as follows:

$$COP_{it} = \beta_0 + \beta_1 * COGS_{it} + \beta_2 * Mkt_{it} + \beta_3 * PBIT_{it} + \beta_4 * Inv_{it} + u_i + \varepsilon_{it} \quad (2)$$

Table 3: Random effect analysis results

Random effects (within) regression		Number of obs	=	163
		Number of groups	=	21
Group variables: CoIndex				
R-sq:		Obs per group:		
Within	= 0.7965	min	=	2
Between	= 0.9357	avg	=	7.8
Overall	= 0.9291	max	=	10
Corr(u_,i,Xb)	= 0 (assumed)	Wald chi2(4)	=	1007.07
		Prob > chi2	=	0.0000

(Source: Author's calculation)

Table 3 presents the results of the random effect regression analysis conducted on the panel data from 26 major utility sector firms over a 10-year period. The analysis determines whether variations in the change in cost of production are better explained by differences across firms (entities) or across time. The random effect model assumes that the entity-specific effects are random and uncorrelated with the independent variables. The result in the table indicates that the selected independent variable has statistically significant impact on variation in the production cost. The model demonstrates that the variability in these factors across firms contributes to changes in production costs. The reported R-squared value of approximately 79.65% suggests that the model explains a substantial portion of the variance in production costs, highlighting the importance of these operational variables and financial variables in the sector's cost structure.

Table 4: Coefficient and Standard error with the p values through random effect analysis

Cost of production	Coefficient	Std. Error	z	P>|z|	[95% Confidence Interval]	
Cost of goods sold	0.157936	0.0350343	4.51	0.000	0.08927	0.22660
Marketing exp.	20.97757	2.41668	8.68	0.000	16.241	25.7142
PBIT	0.478991	0.06485	7.39	0.000	0.35189	0.6061
Inventories	2.838633	0.258817	10.97	0.000	2.33136	3.34591
_cons	-5669.20	5129.55	-1.11	0.000	-15722.9	4384.49
sigma u	17130.53					
sigma e	11943.38					
Rho	0.672909	(fraction of variance due to u_i)				

(Source: Author's calculation)

In Table 4, the variables selected are having significant impact on cost of production. It depicts that production cost is positively impacted by variability in cost of goods sold, marketing expenses, profits and inventories. Higher cost of goods sold (COGS) generally indicate higher cost of production since it includes all expenses directly tied to manufacturing. A rising COGS without a corresponding increase in sales price may signal inefficiencies or increase in input costs. Marketing expenses are not included in the cost of production but can influence production scale. Increased marketing may increase demand, leading to increased production and substantially decrease the per unit production costs due to economies of scale. Desired profit margins influence pricing strategies, which inversely affect production cost decisions. High inventory levels can raise the storage costs and risk of obsolescence, raising the overall cost associated with production. The sigma u measures the standard deviation of the unobserved, firm-specific random effects in the panel data model. A larger sigma u means there is greater variability in cost of production across firms that is not explained by the included variables, but rather by characteristics unique to each firm. Sigma e is the standard deviation of the within firm errors. It indicates that there is substantial unexplained variation in the cost of production within the firms across different years probably due to temporary shocks, measurement error, or omitted time varying variables. Rho (ρ) is the inter-class correlation coefficient that measures the proportion of the total variance in the dependent variable due to differences between firms as opposed to within firms over time. As $\rho = 0.67$ is close to 1, it explains that most of the variation in cost of production is between firms.

The Breusch pagan test has been applied to check whether OLS regression or random effect method should be used to analyse the better results. Its main purpose is to test whether the variance of the random effect is significantly different from zero, indicating that the random effect model is more appropriate than pooled OLS. Under null hypothesis the variance of the random effect is zero. Thus, meaning that there are no panel level effects, so OLS is sufficient. While in alternative hypothesis, the variance of the random effect is not zero suggesting that there is an existence of unobserved heterogeneity and the random effect model is preferred. The test statistics are found to be significant and hence we keep the random effect results and discard the OLS.

Next, fixed effect analysis has been performed which has been shown in Table 5. Variables that have been taken are having significant impact on cost of production. Performing fixed effect regression analysis in panel data study means estimating the effect of independent variables on a dependent variable, while controlling all unobserved, time-invariant characteristics of each entity, using only the variation within each entity over time. It eliminates bias from the omitted variables that are constant within each entity but unobserved, if those do not change over time. The equation is as follows:

$$COP_{it} = \alpha_i + \beta_1 * COGS_{it} + \beta_2 * Mkt_{it} + \beta_3 * PBIT_{it} + \beta_4 * Inv_{it} + \varepsilon_{it} \tag{3}$$

Table 5: Fixed Effect analysis results

Fixed effects (within) regression		Number of obs	=	163
		Number of groups	=	21
Group variables: CoIndex				
R-sq:		Obs per group:		
Within	= 0.8164	min	=	2
Between	= 0.9000	avg	=	7.8
Overall	= 0.8938	max	=	10
Corr(u_,i,Xb)	= 0.5378	F(4,138)	=	153.38
		Prob > F	=	0.0000

(Source: Author's calculation)

The table summarizes the results from the fixed effect regression model. Unlike random effect model, the fixed effect approach controls for all unobserved, time-invariant characteristics of each company, isolating the impact of the independent variables on production costs using only within company variation over time. This method is particularly useful for addressing potential bias from omitted variables that do not change within entities. The results show that independent variables are having significant impact on production costs. The model achieves an R-squared value of approximately 81.64%, indicating strong explanatory power. The fixed effect results suggest that, after accounting for company-specific traits, these operational and financial variables remain key determinants of production costs.

Table 6: Coefficient and Standard error with the p values through fixed effect analysis

Cost of production	coefficient	Std.Error	z	P>│z│	[95% Confidence Interval]	
Cost of goods sold	0.229957	0.3499	6.57	0.000	0.1608	0.2992
Marketing exp.	10.47426	2.6163	4.00	0.000	5.301	15.648
PBIT	0.351983	0.06167	5.70	0.000	0.229	0.474
Inventories	2.209336	0.23272	9.49	0.000	1.7492	2.669
_cons	4176.808	3541.97	1.18	0.000	-2827	11180
sigma u	44922.63					
sigma e	11943.38					
Rho	0.933981	(fraction of variance due to u_i)				

(Source: Author's calculation)

The coefficients given in Table 6 represent the estimated change in each independent variable controlling for all time-invariant company characteristics. The results show that an increase in COGS is associated with a decrease I production costs, while increase in marketing expenses, PBIT and inventories lead to a higher production cost. All variables are statistically significant, as indicated by their low p-values. The table represents the nuanced relationships between operational cost structures in the utility sector, highlighting the importance of efficient marketing and inventory management, as well as the reinvestment of profits, in controlling production costs. Sigma u represents the variability in the cost of production that is due to characteristics unique to each firm, which do not change over time. Sigma e reflects random shocks, temporary effects or measurement errors that affect a firm's cost of production in given year. As rho (ρ) appears to be 0.93 which is closer to 1, it means that most of the variation in cost of production is between firms.

Further, to choose between random and fixed effect model Durbin Wu Hausman test has been performed. The test helps to determine whether a regressor in a model is endogenous (correlated with the error term) or exogeneous (not correlated). The preferred model is random effect. Under null hypothesis the preferred model is random effect, it states both fixed effect and random effect estimators are consistent but random effect is more efficient having lower variance. While the alternative hypothesis considers the fixed effect estimator is consistent, but the random effect model is not due to correlation between regressors and individual effects. The equation for the Hausman test is given as:

$$H = \left(\hat{\beta}_{FE} - \hat{\beta}_{RE}\right)' \cdot \left[Var\left(\hat{\beta}_{FE}\right) - Var\left(\hat{\beta}_{RE}\right)\right]^{-1} \cdot \left(\hat{\beta}_{FE} - \hat{\beta}_{RE}\right) \tag{4}$$

4. Conclusions and Interpretations

The research conducted stresses on significant role of the utility sector in framing India's economic path, highlighting both structural inefficiencies and opportunities for reforms. The study aims to provide comprehensive understanding of the factors that influence production costs in the utility sector, evaluating the role of company and time-specific effects. The analysis reveals that cost of production is influenced by key financial and operational factors in which entity driven heterogeneity plays a significant role. The present study explores how the effect of marketing expenses, inventories, PBIT affects the production cost of 26 BSE listed firms of the utility sector from 2013 to 2023 by using linear regression, random effect and fixed effect analysis. The study revealed that while marketing expenses and inventory management raises the production cost, reinvestment of the profit can promote sectoral expansion. Along with that inefficient working of public owned enterprises and the weight of non-performing assets causes financial risks that demand immediate action.

Through regression analysis it has been seen that cost of goods sold is negatively related to production costs. An increase in the cost of goods sold by one unit leads to a fall in cost of production by 0.94 units. While an increase in market expenses, PBIT and inventories by one unit lead to increase in cost of goods sold by 39.36 units, 0.40 units and 4.65 units respectively. The intercept appears to be -7481.103. The R-squared computed shows 96.21% accuracy. Increased marketing expenses are positively impacting the cost of production. Low-cost marketing and digital marketing are some of the effective ways that reduce expenses. Increased profits can be reinvested in setting up the new production units, that further raises the revenue. Inventories management is an important aspect of the utility sector. It helps to optimize the asset management processes and improves operational efficiency. It also helps to reduce operating costs of the sector. On the contrary, rise in cost of goods sold causes a decrease in cost of production, suggesting efficiency gains or scale effects.

Random effect provides 79.65% accuracy, and all the variables are significantly affecting the cost of production. The p values of all the variables are significant at 5% level of significance. Breusch Pagan Lagrangian multiplier test was applied to choose between OLS regression and random regression. The result shows that random effect is a better approach over OLS regression for the given panel data. After the test, fixed effect regression analysis has been performed, which shows 81.64% accuracy. All the variables are acting significantly towards cost of production.

Having presented the estimates from both random and fixed effect models, it is essential to formally test for endogeneity of the regressors. For model selection, Durbin Wu Hausman test for endogeneity is performed. The null hypothesis (H0) considered is that the random effect is both consistent and efficient and the difference in coefficients is not systematic, indicating that the regressors are exogeneous. While the alternative hypothesis (H1) considers fixed is consistent, indicating that the regressors are endogenous i.e. correlated with individual effects and the difference between the coefficients is systematic. As the probability greater than chi squared is 0.0000, null hypothesis is rejected. Therefore, the preferred model is fixed effect regression analysis. Thus, we can interpret that there is a significant correlation between the individual effects and the independent variables in our model. The model accounts for unobserved heterogeneity by allowing each individual firm to have its own intercept, effectively controlling for time invariant characteristics. The model demonstrates high explanatory power, with an adjusted R-squared of over 96% in the linear regression and over 81% in the fixed effect panel model.

Further in fixed effect, time effect and entities effects are performed. The time effect reveals that none of the time is having a significant impact on the cost of production of the utility sector whereas entity effect concluded that some of the entities are getting significantly impacted by the variables that impact the cost of production of the sector. Several major firms in the sector are significantly affected by factors such as change in cost of goods sold, inventory levels, marketing expenses and profits. Within this group, firms experience positive influences from these variables, particularly in terms of cost management, marketing efficiency, inventory handling and profit before interest and tax. In contrast, other organizations in the same sector are negatively impacted by these sectors, facing challenges that adversely affect their financial performance.

The overall analysis reveals that marketing expenses and inventory management are major problems that increase production costs. Efficient management in these areas can help in minimizing costs. Higher profits (PBIT) can be reinvested for expanding production but may also raise production costs. The presence of significant entity effects means that the company specific characteristics such as management practices, operational efficiency or ownership structure play a crucial role in determining cost of production. The findings showcase the need for targeted strategies at entity level, especially for public sector undertakings that faces financial constraints and inefficiencies. The study further highlights a demand-supply mismatch within the sector, particularly in some enterprises. In contrast, some firms are positively influenced by key operational variables. Stakeholders are encouraged to implement policies that can effectively address the increasing demands of the population to support economic growth. Additionally, the findings indicate that there are no significant time effects, meaning that annual changes do not systematically impact the cost of production across the sector.

Efficient management of marketing and inventories is crucial for controlling production costs. Public sector enterprises that face inefficiencies contributing to increased costs and financial distress. While higher profits can be reinvested to expand production, which may slightly increase production costs, probably due to increased operations or technological upgradation. Persistent demand- supply mismatches, especially in public sector firms highlights the need for better demand forecasting, supply chain management and policy interventions.

The adoption of a more tenacious utility sector requires strategic state interventions that include reforms such as universal meetings, enhanced financial planning and cross-subsidy reductions. Improvements in technology, especially in renewable energy and smart grid technologies create a feasible path towards sustainability and cost efficiency. Data-driven decision-making, infrastructural investment and transparent governance should be the key priorities of the policy makers to attain long term stability in the sector.

To enhance efficiency and production smoothening in India’s utility sector, a robust policy framework should prioritize integrated demand supply management, financial and operational reforms and technological modernization. Policymakers must promote advanced demand forecasting and demand-side management strategies that minimize mismatches and outages, while incentivizing green supply chains practices to reduce environmental impact and operational costs. Regulatory interventions should mandate universal meetings, cross-subsidy reduction, and improved resource planning to ensure accurate billing, financial sustainability and efficient resource allocation. Strengthening corporate governance, especially in public sector undertakings, is essential to improve transparency, accountability and decision-making, while regular performance benchmarking and early identification of non-performing assets (NPAs) will help in mitigating financial distress. The framework should also support targeted interventions for financially distressed entities, linking aid to measurable performance improvements and governance reforms. To future-proof the sector, investments in renewable energy integration, smart grid technologies and digital inventory management must be accelerated, alongside capacity-building programs for employees to foster operational excellence. Lastly, establishing mechanisms for regular policy review, data-driven decision making and stakeholder collaboration will ensure continuous improvement, resilience and sustainable growth in the utility sector, aligning with India’s broader economic and environmental goals.

Research that are conducted in the coming future should study the impact of artificial intelligence, blockchain and energy storage solutions in enhancing grid management and lessening inefficiencies. In addition, a comparative analysis of global utility markets could offer in depth insight into best practices and innovation driven strategies. Focusing on these issues could foster sustainability, efficiency and dynamic utility sector of India.

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