PRODUCTION DYNAMICS OF INDIAN FERTILISER INDUSTRY: AN ANALYSIS OF ITS FACTORS AND STRUCTURAL BREAK

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ABSTRACT

Fertilisers play a key role in the agriculture sector, which is ultimately crucial to meet the agricultural needs of a large population, such as that of India. Due to its significance in the Indian economy, the government has been a significant participant in the industry through the proactive implementation of strategic regulations, policies, and subsidies to ensure stability, growth, and check hindrances in supply. Given the notable nature of subsidies and schemes like the Neem-coated Urea policy, Nutrient-Based Subsidy scheme and Direct Benefit Transfer scheme, it is indicative that government policies play a vital role in the production and consumption of fertilisers. Further, there are several other non-governmental internal and external forces and factors that act as determinants of fertiliser industry's growth in India. This study attempts to find the shift in production trend through a structural break test to find the impact of these policies and regimes on production. In addition, it also aims to find the factors that impact the industry's growth and the causal effect of these factors on the production of fertilisers in India. For fulfilling the objectives, structural break analysis, Principal Components analysis and Linear Regression analysis have been used. Findings suggest multiple non-random break points in the production trend, thus suggesting the presence of structural breaks due to policy implementations. Further, using factor analysis, three chief factors were extracted, and these factors furthermore displayed a significant impact on production. These outcomes demonstrated that the fertiliser industry is not linked with only one factor, but rather a collective and complex interplay between global market conditions, domestic agricultural situation, state interventions, and infrastructural capabilities.

Keywords: Fertiliser Industry, Subsidy, Fertiliser Production, Structural Break, Principal Component Analysis

I. INTRODUCTION

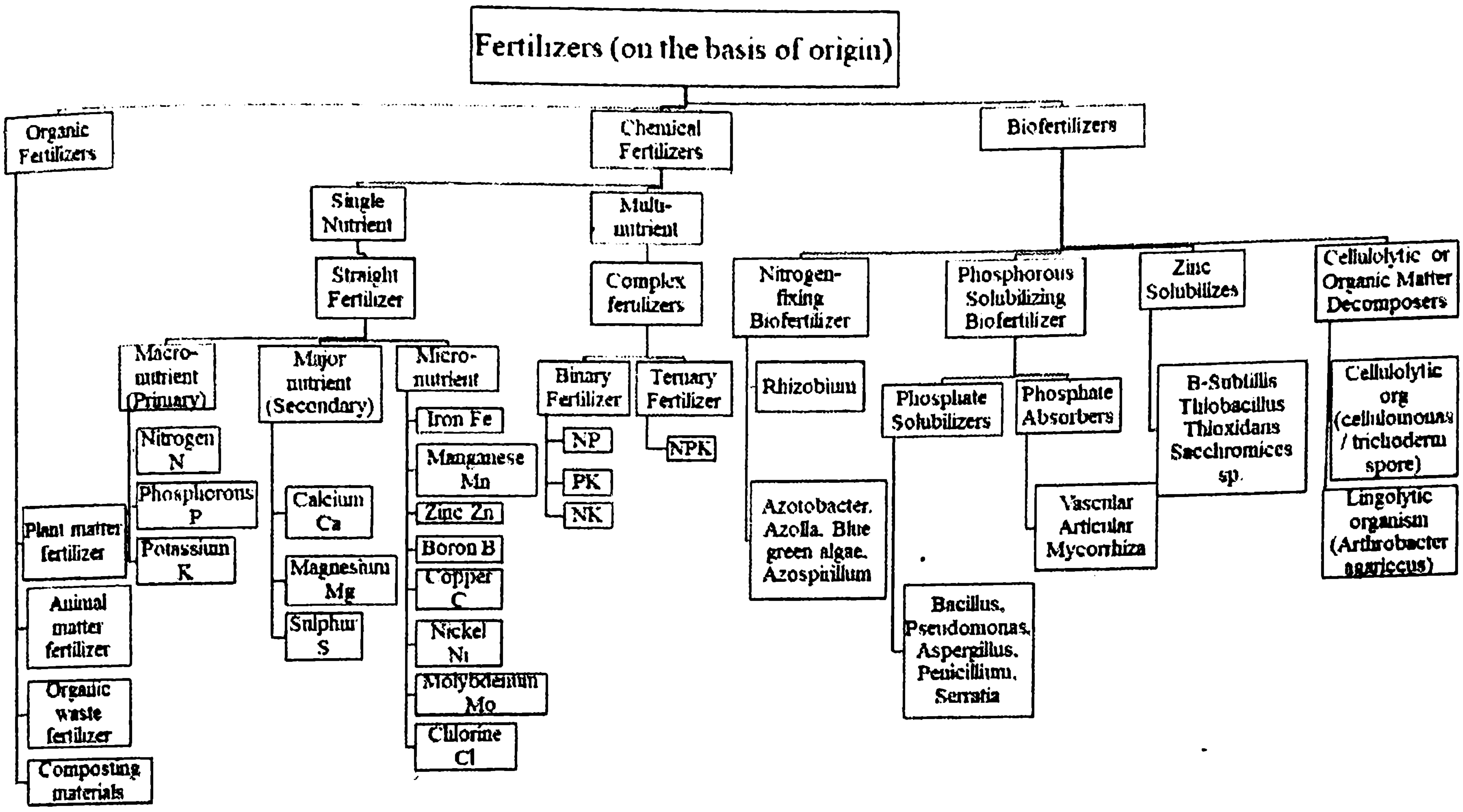
Over the past two decades, the dependence of India's Gross Domestic Product (GDP) has gradually shifted towards services sector from agriculture, though the latter remains a key sector in terms of employment, especially in the rural parts of India. From a share of 50-60% in the early years of independence, the contribution of agriculture has declined to as low as 20.2% in 2020-21. However, even at a one-fifth contribution, the sector employs more than 50% of the workforce (Economic Survey, Ministry of Finance, 2021). Owing to the sustained agriculture reforms in the past few years, India has been able to remarkably attain self-sufficiency in food grain production to serve the second-highest population in the world. On the other hand, the aggressive level of agricultural production has led to the decline in soil fertility and this decline has driven towards the increasing use of fertilisers. Fertilisers play a key role in the agriculture sector, which ultimately is crucial to meet the needs of such a large population. This growing requirement has led to an increase in fertiliser demand and to enhancement of productivity (Pathak et al., 2014). Fertilisers are crucial to agricultural production because they give crops the nutrients they need, thus enhancing both the quality as well as quantity of agriculture produce.

The history of the Indian fertiliser industry dates back to the beginning of the twentieth century when the first fertiliser factory was set up in Ranipet, Tamil Nadu, back in 1906. Since 1960-61, India has been one of the leading producers of Nitrogen Phosphorus and Potassium (NPK) fertilisers. Government has been an active participant in the fertiliser industry through proactive implementation of strategic regulations, policies, and subsidies to ensure stability, growth, and check hindrances in supply. The industry is regulated and monitored by the ministry of chemicals and fertilisers through the Department of Fertilisers, the main functions of which are planning, promotion, and development of the fertiliser industry, planning and monitoring of production, and import and distribution of fertilisers, During 1966, as a part of green revolution and based on the recommendation of Sivaraman Committee Report (1965), the fertiliser market was liberalised thus giving freedom to manufacturers to market upto 50% of their production. Furthermore, by 1969, the domestic manufacturers were given complete freedom in marketing.

During the mid-1970s, the global price of fertilisers and raw material such as natural gas, crude oil etc. increased drastically due to the 1973 oil crisis triggered by Arab-Israeli war. In order to tackle the inflated price and meet partially, the increasing cost of production and import, the government introduced fertiliser subsidy for the first time in 1976. Since then, there has been several reforms, amendments in the subsidy policies. For instance, Nutrient Based Subsidy (NBS) was launched in 2010 with the aim to promote balanced fertiliser production through newly fortified products and lead to increasing the agricultural production. During 2016-17, the Direct Benefit Transfer (DBT) scheme was introduced on a pilot basis, which later saw a Pan India rollout in March 2018. Under the scheme, subsidy was routed through the fertiliser industry to the farmers, rather than traditional DBT scheme of transferring the subsidy directly to the bank account of the beneficiaries. Instead of changing the path of subsidy transfer, only the procedure of disbursement was changed.

Given the critical nature of schemes like the Neem coated Urea and NBS, it is apparent that the government engrossed into not just the quantitative production but also the qualitative aspect of type of fertilisers produced and consumed. Based on the origin, fertilisers can be of three types- Natural or Organic fertilisers, which are obtained through non-chemical ways from natural biogenic substances, Chemical fertilisers, which are inorganic, factory-made and mineral based fertilisers, and Bio-fertilisers that contain biological components of living organisms (Randive et al., 2021). A detailed classification of fertilisers is given in Figure 1 for further details. Nitrogenous, Phosphatic and potassic (NPK) fertilisers are some of the common chemical-based fertilisers used in India. A combination of these or several other simple and single element-based fertilisers are called complex fertilisers such as DAP (Diammonium Phosphate). Urea, which has an NPK content of 46%, is the most common type of fertiliser used in India, due to its abundant availability economical nature. Other than Nitrogen, crude oil and natural gas acts as a key input raw material in the fertiliser manufacturing process. History and even research in the field has showed that the price of fertiliser is heavily dependent on natural gas and crude oil (Babula & Somwaru, 1992).

FIGURE 1:CLASSIFICATION OF FERTILISERS



Source: Japan Fertiliser& Ammonia Producers Association, (2003; Randive et al., (2021)

Although the government has been successful in absorbing the price sensitivity of fertilisers to some extent, through policies and subsidies, yet it is often noticed that production and import gets hindered in several instances. In 2018, India emerged as the third largest producer in the world, and second largest consumer, and due to this immense demand, it is also a key global importer. A lot of fertilisers imported in India are phosphate based. Over the past few years, the demand for fertilisers has seen a significant surge in growth, however the average intensity of fertiliser use still remains very low as compared to some developed countries (Bishnoi et al., 2020). Focusing on nitrogen fertilisers, production has shown a gradual growth recently. The total production of fertilisers (N+P+K) increased from around 37 million tonnes in 2013-14 to approximately 45 million tonnes in 2022-23, reflecting a compound annual growth rate (CAGR) of 2-3%. Urea, the most widely used nitrogenous fertiliser, dominates production, with output rising from 24 million tonnes in 2013-14 to 31 million tonnes in 2022-23.

Throughout the history of independent India, it has been very much clear that fertilisers are crucial to the development of the country, and in order for the industry to develop, there are several factors that are needed to be considered. Several elements in the system play a vital role in enhancement of the industry's growth as well as bring hindrances into the growth. These factors include input material, agricultural growth, government policies and subsidy, and even country's economic growth at large. Hence, it is crucial to study these factors and their interplay within the industry so as to formulate evidence-based policies, input efficiency, optimize resource allocation, and ensure sustainable agricultural development.

II. EXISTING LITERATURE, RESEARCH GAPS AND OBJECTIVES

Considering the awareness regarding social and environmental sustainability alongside financial sustainability, and the growth of organic farming, the demand for chemical fertilisers has not seen a reduced surge in demand. Instead, the growth of production has been gradually increasing. Contradictorily, as stated in the previous section, the production has seen a gradual upward trend. This is resultant of several factors coming into play collectively. Historically, the evolution of this sector has been loosely linked to the Green Revolution era and subsequent policy driven growth. Several other governmental policies including adoption of NBS scheme, and neem-coated urea policy have also been a key factors driving the widespread fertiliser adoption (Chand & Pandey. 2009). According to Gulati & Banerjee, (2015), by linking subsidy to nutrient content, the NBS scheme aims at promoting a balanced fertiliser use. However, the uneven use of the scheme leads to excess reliance on urea. They also highlighted three key issues related to India's fertiliser subsidy policy, rising amount of subsidy in budgets, misuse of urea, and rising import of fertiliser due to a dearth in investment flow into the industry at home and delayed payment into the industries.

Bishnoi et al., (2020) and Das et al., (2019) in their respective studies in selected regions highlighted that excessive use of chemical fertilisers particularly urea and NPK leads to reduction in soil potassium level thus declining the soil fertility. The government of India has thus promoted schemes and products such as bio-fertilisers and Neem coated urea to mitigate these issues. Several other studies have stressed upon the ill-effects of using chemical fertilisers (Abbasi, 2022; Gattani et al., 1976; Sapp et al., 2015; Tang et al., 2022). A study by Zhang et al., (2020) found that nitrogen-based fertilisers contribute significantly to nitrous oxide emissions, which is a potent greenhouse gas. Growing acceptance of the negative consequences of chemical fertilisers has spurred interest in sustainable alternatives of chemical fertilisers in form of organic and bio fertilisers. These products combine nutrient-bearing minerals with biological agents and organic matter to promote soil microbial health, nutrient cycling, and overall soil fertility, contributing to productivity maintenance in a sustainable manner (Syed et al., 2021). A study conducted in sub-Saharan Africa called attention to bio-fertilisers as a potential tool for increasing productivity and profitability of small farmers which can help alleviate poverty, and maintain and improve ecological stability(Obayelu et al., 2021).

Ever since their introduction in the 1970s, subsidies play a vital role in enhancing food security, supporting farmers' income, and ensuring equitable resource in the agriculture sector. Fertiliser subsidy accounts for the largest fiscal subsidies after food subsidy in India. As a percentage of GDP, it has grown gradually from 0.38% in 1980-81 to 0.68% in 2020-21 (Ansari & Sheereen, 2022). According to Obayelu et al., (2021), agricultural input subsidies, specifically targeted at impoverished farmers, can serve a dual purpose: providing social protection and significantly boosting agricultural outcomes. By making essential inputs more affordable, these subsidies empower a large number of small-scale farmers, increasing their purchasing power. This, in turn, leads to greater use of agricultural inputs, higher production of food crops, and improved overall food productivity. The resulting increase in food supply contributes to lower food prices, while also enhancing access to nutrient-rich foods, ultimately strengthening both food and nutrition security for the broader population.

Recent studies have attempted to explore the key drivers of fertiliser industry's growth and forecast the future demand and consumption using various advanced statistical tools. For instance, Chakraborty (2016) estimated a demand function identifying the main factors effecting its consumption and forecasting the future demand of fertilisers in India. They found that non-price factors such as production, subsidy, and import have a strong impact on fertiliser demand. They also found that subsidy is strongly related to import, and domestic price. In a similar study carried out by Sharma & Thaker, (2011), they used variables such as short term credit, irrigated area, area under high yielding variety crop, price of rice and wheat, and domestic price of fertiliser. They found the variables to be strongly significant, although HYV crops and irrigated land were more powerful in influencing the demand for fertilisers. Another study predicted that fertiliser demand is likely to grow up to 57 million tonnes and the consumption level to reach 277 kg per hectare by 2030 (N. Sharma, 2022).

The fertiliser industry has several opportunities as well as challenges to face in its way. It is a at the core of not just the agriculture sector but also the industrial base of the country, which makes efficiency and sustainable management crucial for its long-term growth (Mittal et al., 2014). Existing literature on the topic has examined broad trends in fertiliser production and consumption and the role of governmental policies and regimes in specific terms. There is a lack of empirical studies analysing the effectiveness of recent policy and how they have impacted the production process in general. Another critical research gap lies in the systematic identification and quantification of factors affecting fertiliser production, whether internal or external factors.

Considering these gaps in the available literature and the significance of these factors, this study aims at fulfilling the gaps through the following objectives of the study:

1. To detect a significant shift in trend in fertiliser production resulting from key policy reforms and changes in regulatory regimes.
2. To explore the factors effecting fertiliser production in India.
3. To find the impact of the factors on fertiliser production.

III. METHODS

The study is quantitative in nature, employing empirical analysis to establish a causal relationship between the dependent variable and independent variables. The research is based purely on secondary data that has been collected manually from various governmental and non-governmental websites. Some of the sources include Department of fertilisers, NABARD (National Bank for Agriculture and Rural Development), CMIE (Centre for Monitoring Indian Economy), World Bank and Ministry of Statistics and Program Implementation. The study has been conducted for a period of 32 years, ranging from 1991-92 to 2022-23, thus focusing specifically on the post-reform period.

As already discussed in the previous section, the general aim of the study has been classified into multiple specific objectives; hence, for the fulfilment of these objectives, multiple research methods have been employed. In order to check for the structural break, Bai & Perron, (1998, 2003) has been used, with an intention to check for multiple breakpoint. Subsequently, Principle Component Analysis (PCA) has been employed for the purpose of dimensions reduction and factor Analysis. Furthermore, using the factors extracted and their respective values, Ordinary Least Squares (OLS) Regression has been adopted in order to build a causal relationship between the factors and the dependent variable, which is the annual production of fertilisers in India. However, before applying OLS regression, it is crucial to pre-test the dataset in regards to the assumptions of OLS. Hence, the basic assumptions, including normality of error terms, multicollinearity, and autocorrelation, were also checked before carrying on with OLS regression. The detailed list of variables used in the study has been enumerated in the TABLE 1.

TABLE 1: VARIABLES LIST

Variable	Category	Abbrev.	Details
Production	Dependent	prod	Annual chemical fertiliser production ('000 metric tonnes)
Agriculture production	Independent	lagr	Log of annual total agricultural produce value
Cropped production index	Independent	crop	Index of food crop (base year: 2014-15)
Gross cropped area	Independent	gcar	Total grossed cropped area (000'hectares)
Exchange rate	Independent	excr	Average annual exchange rate of USD/INR
Global crude oil price	Independent	gcro	Average annual global crude oil price (USD per barrel)
Global fertiliser price	Independent	gftp	Global fertiliser price (USD/tonne)
Natural gas global price	Independent	nggp	Global price of natural gas (USD/million British thermal units)
Fertiliser subsidy	Independent	fsub	Annual fertiliser subsidy value (crore rupees)
Import	Independent	impt	Annual fertiliser imports value (crore rupees)
Precipitation	Independent	rain	Average annual rainfall (in mm)
Foodgrain Production	Independent	fgpr	Annual production of cereals and pulses (000'metric tonnes)
Number of factories	Independent	nofc	Nationwide number of active fertiliser factories (number)

Source: Authors

IV. EMPIRICAL RESULTS

This study is broadly two-fold; firstly, we attempted to check if government schemes and policies including the neem-coated urea policy, direct benefit transfer of subsidy, and nutrient based subsidy policy had any impact on the production and growth of the industry in India, and secondly, we analysed the factors that enhance or decrease the growth of the industry.

BREAK POINT ANALYSIS

For the first objective, i.e., to find the structural break, we used Bai & Perron, (1998, 2003)'s multiple breakpoint test to detect and analyse structural break in the time series data of production. This test allows to check for multiple break points endogenously, i.e., without specifying the timing of break. TABLE 2 and TABLE 3 represent the outcome of the test. The tables reveal the statistically significant (at 5% level) breakpoints occurring in 1997, 2009, and 2015. The extremely high F-statistic (significantly higher than the critical value) provides strong evidence of a structural break at the three instances. The sequential break point suggests 2009 as the most prominent breakpoint, while the repartition suggests 1997 as the most crucial.

TABLE 2: BREAK POINT TEST

Break Test	F-Statistic	Critical Value**
0 vs. 1*	59.85793	8.58
1 vs. 2*	49.91201	10.13
2 vs. 3*	25.27474	11.14
3 vs 4*	7.42221	11.83

Source: Authors

**Significant at 5% level*

TABLE 3: SEQUENTIAL AND REPARTITION BREAKPOINTS

Break	Sequential	Repartition
1	2009	1997
2	1997	2009
3	2015	2015

Source: Authors

PRINCIPAL COMPONENT ANALYSIS

In order to fulfil the next set of objectives, we undertook Principal Component Analysis (PCA) approach. The variables used in the study were reduced using PCA, thus reducing the chances of multicollinearity and filtering the noise, focussing on high-variance components. TABLE 4 reveals the descriptive statistics and the data characteristics. Fertiliser production for the time period varies between 21,684.20 thousand tonnes and 48,698.60 thousand tonnes, with the mean and standard deviation values of 34,861.25 and 6745.99 thousand tonnes respectively. In the same time period, the import value ranged between 3100 and 23141.7 thousand MT with a mean import value of 11,823 thousand MT and a very high standard deviation of 6,752 thousand MT. Interpreting the fertiliser subsidy, it can be seen that there is a high variation in the values ranging between ₹5185 and ₹1,33,947 crores with the mean and standard deviation being ₹43,074 and ₹35363.52 crores.

TABLE 4: DESCRIPTIVE STATISTICS

Variable	N	Minimum	Maximum	Mean	Std. Dev.
Prod	32	21684.200	48698.600	34861.247	6745.9904
Lagr	32	10.870	11.750	11.2753	0.29686
Crop	32	53.310	123.290	82.2422	21.46542
Gcar	32	113860.000	140427.500	126056.394	5441.3540
Excr	32	22.742	78.604	49.4275	14.81704
Gcro	32	15.899	95.264	51.6618	26.72891
Gftp	32	30.456	235.736	78.3704	50.56739
Nggp	32	1.815	10.166	4.1032	2.14544
Fsub	32	5185.000	133947.000	43074.06	35363.520
Impt	32	3099.300	23141.700	11822.9150	6751.82618
Rain	32	929.220	1301.330	1118.8575	85.73932
Fgpr	32	113860.000	140427.500	125933.4188	5398.17557
Nofc	32	388.000	772.000	605.50	137.668

Source: Authors

TABLE 5 shows the pre-test statistics of the analysis. Kaiser-Meyer-Olkin (KMO) measure, which indicates the sample adequacy of the data for factor analysis, is 0.75, which is more than the acceptable level of 0.5 (Hair et al., 2006). Thus, it can be safely accepted that the sample size is adequate for the study. Bartlett's test of sphericity is used to assess the suitability for factor analysis, by checking the presence of correlation between the variables. The chi-square value of 600.01 suggests is strongly significant at all levels, thus rejecting the hypothesis of multicollinearity and confirming the suitability of the test.

TABLE 5: KMO AND BARTLETT TEST

Test Type	Value
KMO Measure of Sampling Adequacy	0.752
Bartlett's Test of Sphericity - Chi-Square	600.014
Degree of freedom	66
Sig.	0.000

Source: Authors

Communalities as represented in TABLE 6 reflect the strength of each extracted factor in explaining the variance of the variables under assessment. All the values are amply high (more than 0.8), which signifies a strong explanatory power of the extracted factors. Figure 2 showing the scree plot below reveals that out of the 12 extracted components, 2 have an eigen value greater or equal to 1. However, it is also clear that the 3rd component has an eigen value very close to the elbow or inflection point (0.98) and towards the right of this, the slope flattens significantly. Thus, for the purpose of the study, we have chosen the first 3 components. For extracting the factors, we have used Varimax rotation method. It redistributes the variance in such a way that the percentage of variance of the factors and factor-loading pattern become different. According to TABLE 7 and FIGURE 2, out of 12 factors extracted, 3 have been chosen to extract the solutions. Total variance explained by these three factors cumulatively is 86.85% which is reasonably ideal for the study as it explains significantly more than 50% of the variance.

Rotated component matrix is one of the key outputs of PCA. As reflected in TABLE 8, all the variables under study have been assigned their respective factor loading values in the three components. For simplification of the output, only significant coefficients of all variables have been displayed, while smaller coefficients (less than 0.6) have been suppressed. As per the table, a total of 12 variables have been clubbed to form the three components or factors. The first component has the strongest representation of the model consisting of factor loading of 8 variables while the remaining 4 variables are divided among component 2 and 3 with 2 variables each that have a factor loading of more than 0.6. This outcome has been presented in TABLE 9. Based on the characteristics and type of variables clubbed into them, the factors have been named as follows: Factor 1 has been named agriculture economic performance and market dynamics as the variables included in it influence the external input environment and agriculture viability, factor 2 has been named Production and land use intensity, since it consists of food grain production and gross cropped area which reflects the core intensity and scale of agriculture activities being performed, and finally factor 3 has been called industrial and energy infrastructure as it consists of number of factories and global price of natural gas. These variables reflect the production capacity and cost of input.

TABLE 6: COMMUNALITIES

Variable	Initial	Extraction
lagr	1.000	0.965
crop	1.000	0.957
gcar	1.000	0.964
excr	1.000	0.872
gcro	1.000	0.877
gftp	1.000	0.876
nggp	1.000	0.863
fsub	1.000	0.891
impt	1.000	0.915
rain	1.000	0.418
fgpr	1.000	0.968
nofc	1.000	0.854

Source: Authors

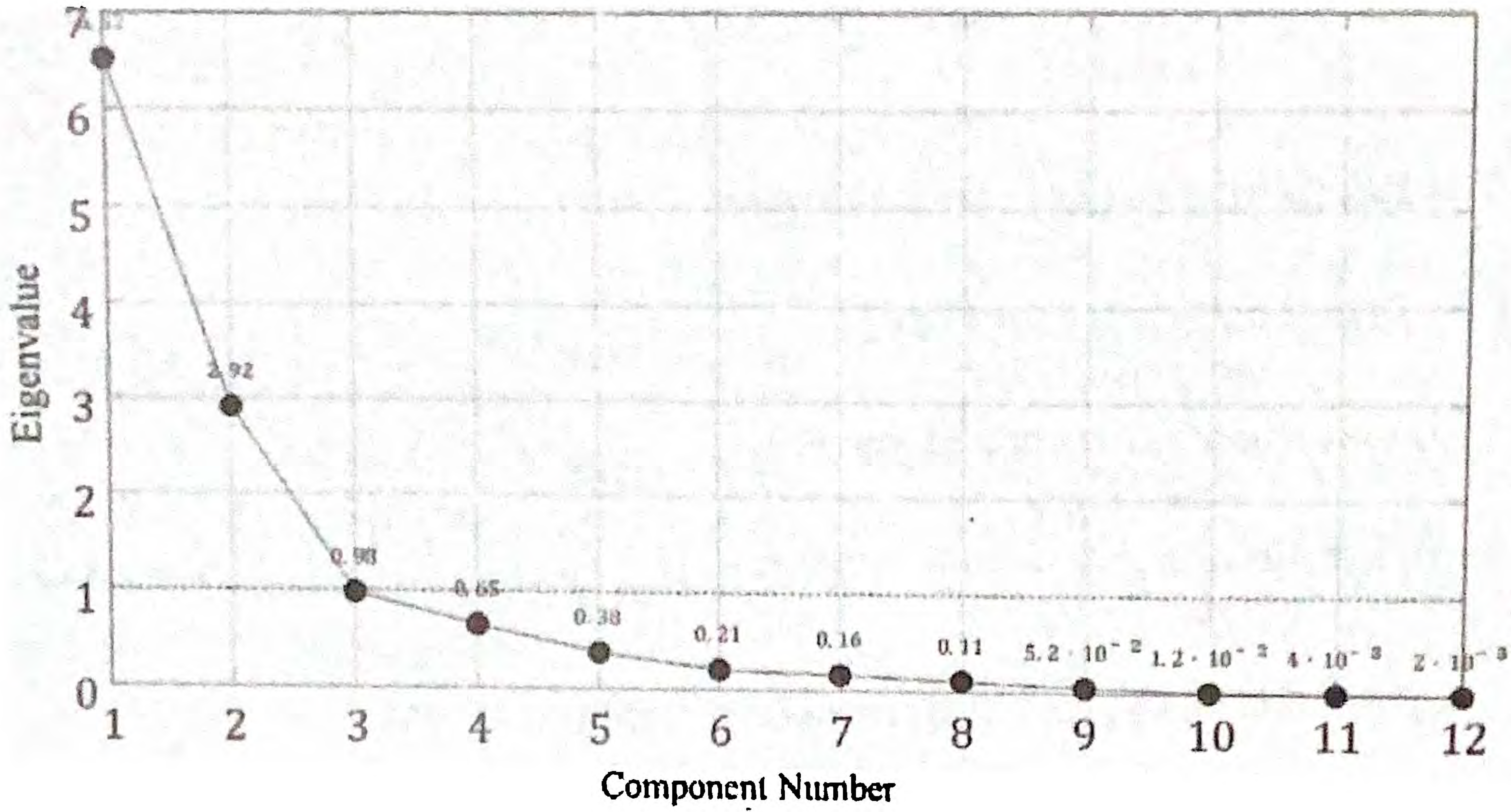
TABLE 7: TOTAL VARIANCE EXPLAINED

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	6.522	54.346	54.346	6.522	54.346	54.346	6.407	53.394	53.394
2	2.918	24.315	78.661	2.918	24.315	78.661	2.414	20.113	73.507
3	0.982	8.186	86.847	0.982	8.186	86.847	1.601	13.340	86.847
4	0.654	5.448	92.295						
5	0.376	3.132	95.426						
6	0.206	1.720	97.146						
7	0.162	1.352	98.498						
8	0.109	0.912	99.410						
9	0.052	0.430	99.840						

10	0.012	0.104	99.944		
11	0.004	0.037	99.981		
12	0.002	0.019	100.000		

Source: Authors

FIGURE 2: SCREE PLOT



Source: Authors

TABLE 8: ROTATED COMPONENT MATRIX

Variable	Component 1	Component 2	Component 3
Agriculture production	0.960		
Cropped production index	0.952		
Exchange rate	0.818		
Global crude oil price	0.780		
Global fertiliser price	0.852		
Fertiliser subsidy	0.942		
Import	0.954		
Avg. Annual precipitation	0.627		
Foodgrain Production		0.953	
Gross cropped area		0.960	
Number offactories			0.610
Natural gas global price			−0.784

Source: Authors

TABLE 9: FACTORS DESCRIPTION

Factor 1 (53.39%) (Agriculture Economic Performance and Market Dynamics)	Factor 2 (20.11%) (Production and land use intensity)	Factor 3 (13.34%) (Industrial and Energy Infrastructure)
Agriculture's contribution to GDP	Food grain production	Number of factories
Crop production index	Gross cropped area	Natural gas global price
Exchange rate		
Crude oil price		
Global fertiliser price		
Fertiliser subsidy		
Import		
Average annual rainfall		

Source: Authors

REGRESSION ANALYSIS

After performance of PCA, reduction of dimensions and extraction of factors, the subsequent step is concerned with regression analysis and its outcome. Before per forming the necessary tests, we checked for the fulfilment of assumptions of linear regression. For the test of normality, Jarque-Bera test reveals that the data is normally distributed due to the p-value being more than 5% (TABLE 11). Further, the Durbin-Watson statistic value is 1.553, hence, the presence of serial autocorrelation can be dismissed (TABLE 12). Finally, the VIF score of 1 in case of all independent variables in TABLE 13 suggests absence of multicollinearity in the dataset. Fulfilling these assumptions, it is safe to go for performing regression analysis. Firstly, the R square value of 0.907 in TABLE 11 implies that 90.7% of the total variation in dependent variable can be explained by the independent variables chosen for the study. The high value of both R square and adjusted R square reflects strong goodness of fit. Secondly, the F statistic is significant at all levels (sig-0.000), thus confirming model fitness. Finally, the three predictors have strong coefficients that are significant at 5% level. This reflects that the independent variables collectively as a factor can explain a variation in dependent variable significantly.

FIGURE 3: HISTOGRAM (NORMALITY TEST)

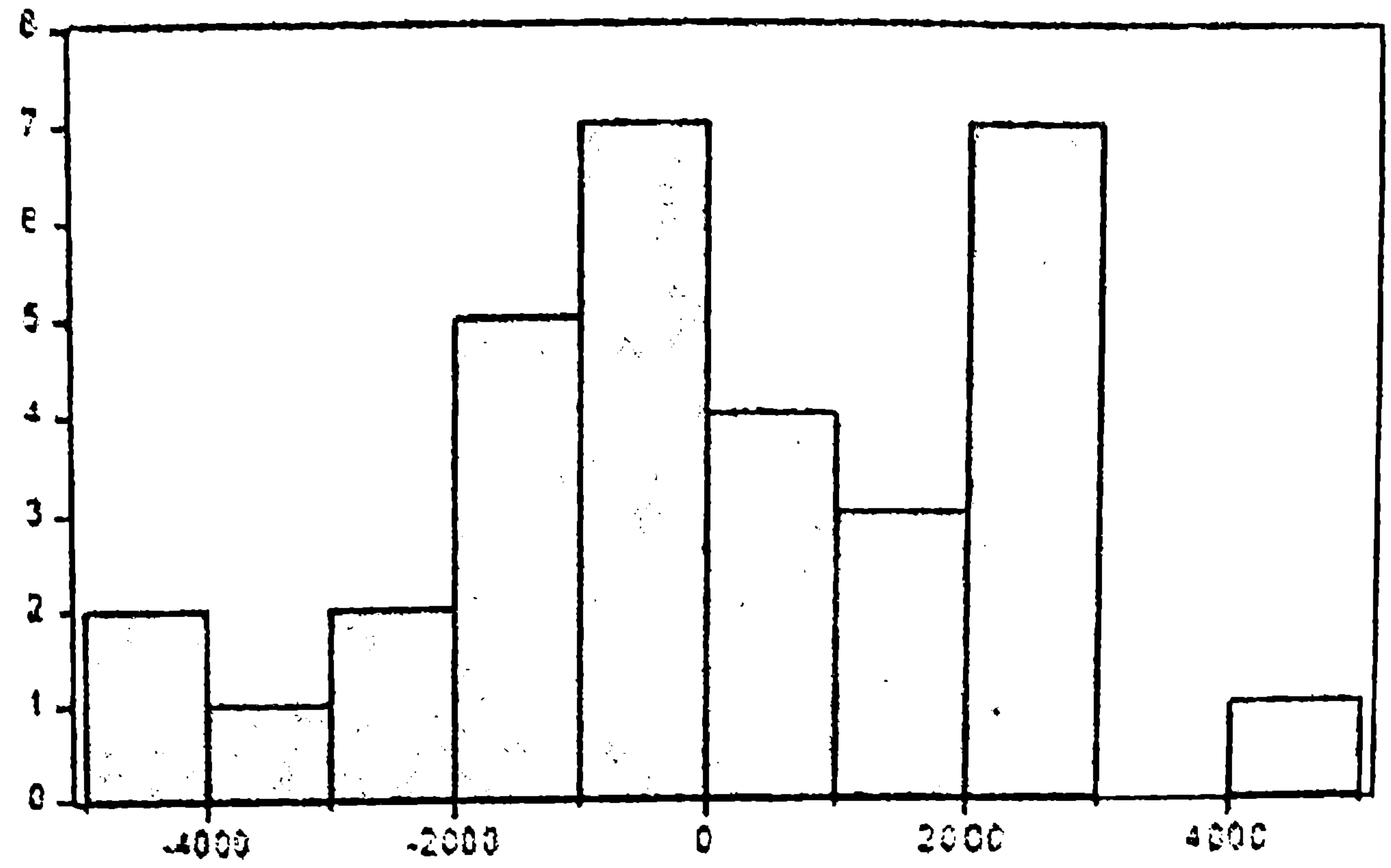


TABLE 10: NORMALITY RESULTS

Statistic	Value
Sample	1991-2022
Observations	32
Mean	-6.65×10^{-12}
Median	−42.30357
Maximum	4442.891
Minimum	−4515.313
Std. Deviation	2256.462
Skewness	−0.121240
Kurtosis	2.295989
Jarque–Bera	0.739238
p-value	0.690998

Source: Authors

TABLE 11: REGRESSION MODEL AND ANOVA SUMMARY

R	R Square	Adj R Square	Std. Error	Durbin-Watson	F (ANOVA)	Sig.
0.952	0.907	0.897	2169.0907	1.553	90.615	0.000

Source: Authors

TABLE 12: REGRESSION COEFFICIENTS

Predictor	Coefficient	Std. Error	t	Sig.	VIF
Constant	34861.247	383.445	90.916	0.000	
Factor Score 1	5796.247	389.580	14.878	0.000	1.000
Factor Score 2	2654.169	389.580	6.813	0.000	1.000
Factor Score 3	785.913	389.580	2.017	0.048	1.000

Source: Authors

V. DISCUSSIONS

The empirical findings of the study provide crucial insights into the pervasive dynamics of Indian fertiliser industry. Firstly, the break point analysis reveals three structural breaks in the years 1997, 2009, and 2015. This signifies that there was a change in trend of fertiliser production in India during these three instances either due to policy shock, external shock or change in economic regimes. The break in 1997 likely corresponds to the post-reform impacts of India's economic liberalisation of the early 1990s. Further, the P&K fertilisers were decontrolled in 1992. These policy changes resulted in price volatility. Conclusively, the 1997 breaks mark the shift from state-controlled pricing to market regulated pricing policy. Conforming to this, Ghosh, (2010) found a structural break in agriculture output in 1998-99, which complies with the break in this study. The next break in 2009 indicates a change due to global commodity shock and domestic policy. The aftermath of global financial crisis of 2008 and the increase in India's fertiliser subsidy bill due to rise in global price can be linked to the shock. Finally, the break in 2015 can be directly associated with the introduction of neem-coated urea policy across India. The direct benefit transfers though launched in 2016, was also in focus during this time.

Secondly, the factor analysis reveals three latent dimensions that collectively explain a substantial portion of the variance in fertiliser-related outcomes. The variables which have high loading on the first factor (Agriculture economic performance and market dynamics) are closely tied with both macroeconomic variables and global input market. The prominence of crude oil price under this factor highlights India's sensitivity to global commodity trend due to its reliance of import of not just fertiliser final products but also raw material. The second factor, Production and land use intensity comprises of food grain production and gross cropped area. These variables directly point out the fact that fertiliser demand is directly based on agricultural productivity. The third factor labelled as industrial and energy infrastructure consists of number of factories and global price of natural gas which is a crucial input for fertiliser production. Individually, the negative loading of natural gas price (-0.784) reflects how an increase in energy price can affect fertiliser production adversely. This concern is especially pertinent in case of urea production since it is directly dependent on natural gas as a feedstock. Thirdly, the regression results using the extracted factors as independent variable confirms the statistical significance of these factors. With a high R^2 value of 90.7%, the model demonstrates how well the factors explain the variance in fertiliser production in India. The coefficient is highest in case of first factor as it has the highest factor loading on most of the variables, thus most of the variance is explained by this factor, followed by second and third factor. In case of third factor, although the coefficient is low, but still significant.

VI. CONCLUSION AND RECOMMENDATIONS

This study set out to explore the key determinants influencing the fertiliser production and usage from 1992 to 2022. Using a combination of structural break analysis, PCA and regression modelling, the research identified three major underlying dimensions shaping the fertiliser industry: Agriculture economic performance and market dynamics, Production and land use intensity, and industrial and energy infrastructure. Our findings demonstrated that the fertiliser industry is not linked with only one factor, but rather a collective and complex interplay between global market conditions, domestic agriculture situation, state interventions, and infrastructural capabilities. The three structural breaks are not random but correlate closely to the external and internal transactions. In conclusion, India's fertiliser industry stands at the intersection of agriculture, energy, environment, government interventions, and economics. The abundance in demand of fertiliser cannot be fulfilled simply using current resources available. Despite the increase in production value throughout the years, import has not seen any decline, whether short run or long run. This exceeding dependence on global trade can result into a dire situation. As the nation strives towards self-reliance in food production and sustainable agriculture, the insights from this study provides valuable feedback towards updating of infrastructure for fulfilling the domestic demand sufficiently through domestic production.

From the above findings and discussions, several crucial policy directions emerge. Firstly, given the strong influence of input prices, there is a need to enhance the input price stability through strategic international agreements. Secondly, subsidies play a key role, as captured in the first factor. Thus, a more effective and transparent subsidy scheme is needed for smooth fertiliser delivery. Direct benefit transfer directly to the farmer rather than the producer can reduce inefficiencies and provide support directly to the smallholder farmers. Thirdly, policies should focus on increasing the domestic fertiliser production capacity so that the dependence on imports and global markets can be reduced, giving way to self-sufficiency and self-reliance. Finally, in the wake of awareness regarding sustainable growth and environmental protection, the ill effects of chemical fertilisers cannot be neglected. Therefore, it is vital to focus on bio-fertiliser and organic fertiliser production in order to enhance efficiency and mitigate environmental impact and promote sustainable development.

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