Edible Oil Self-Sufficiency in India: A PCA-VECM Approach

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ABSTRACT:

Between 2019 and 2022, India's edible oil import value surged from USD 9.68 billion to USD 21.18 billion before declining to USD 16.41 billion in 2023. Rising domestic demand prompted the government to reduce import duties in 2021 to curb inflation caused by factors such as the COVID-19 pandemic, the Russia-Ukraine conflict, labour shortages, and supply-chain disruptions. Although this policy primarily affected import value, it did not reduce import volumes, which rose from 156 lakh tonnes in 2019 to 162 lakh tonnes in 2023. This highlights India's dependence on major suppliers like Indonesia, Malaysia, Argentina, and Brazil, driven by growing domestic demand to meet the nutritional needs of its vast population. Despite initiatives such as the National Food Security Act, the Public Distribution System, and the Minimum Support Price (MSP) scheme, which aim to reduce import dependence, India's domestic production meets only 40% of its consumption needs. Rising population, urbanisation, income growth, and changing dietary habits have perpetuated the demand-supply imbalance. The reliance on imports exposes India to global price shocks and supply disruptions, disproportionately impacting low-income households and raising food security concerns. Additionally, the shift toward biofuel production in exporting nations diverts resources away from food markets, exacerbating supply constraints. Using a two-step analytical approach, this study examines India's edible oil market dynamics from 1981 to 2021. Principal Component Analysis (PCA) constructs demand and supply indices by capturing underlying dynamics and reducing dimensionality. A Vector Error Correction Model (VECM) further explores short-term interactions and long-term equilibrium among cointegrated variables. Results reveal that imports drive surplus ending stocks, suppressing local production incentives despite the availability of MSPs. Approximately 57% of demand disequilibrium and 68% of supply disequilibrium are corrected per period, stabilising the market within three to five years of a shock. Policy interventions are essential to reduce import dependency and address supply chain inefficiencies.

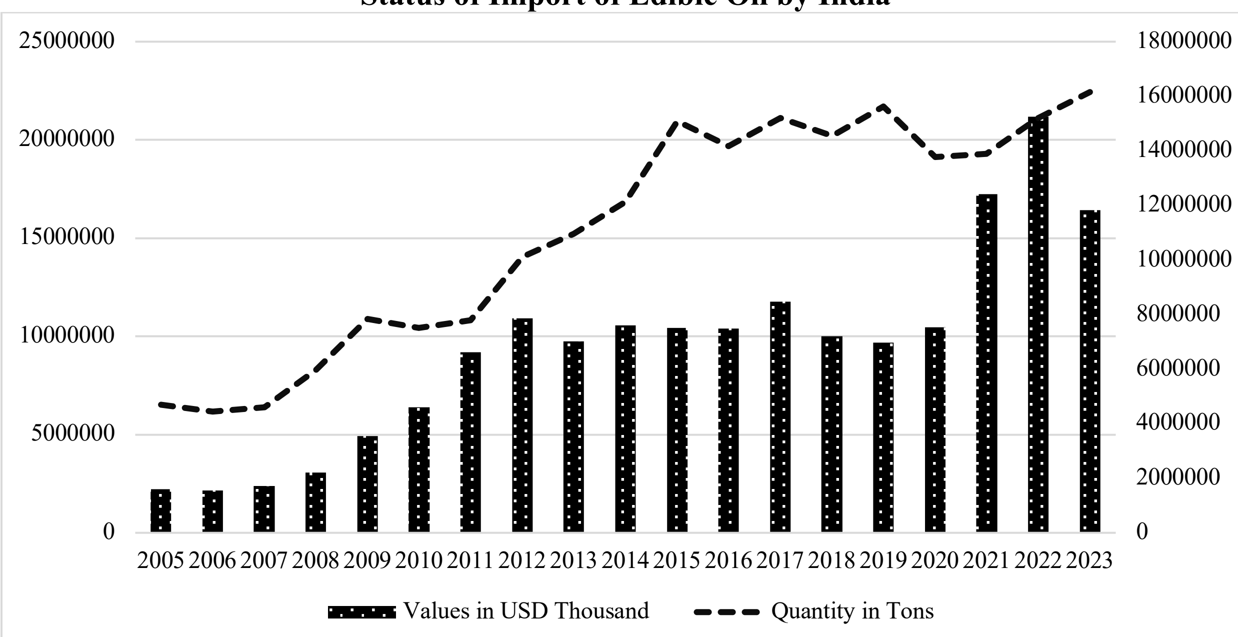
I. INTRODUCTION:

India witnessed a significant surge in the import value of edible oils between 2019 and 2022, doubling from USD 9.68 billion in 2019 to USD 21.18 billion in 2022 before declining to USD 16.41 billion in 2023 (Figure 1). In response to growing domestic demand, the Indian government reduced import duties in 2021, aiming to boost domestic availability and mitigate inflationary pressures arising from various factors. These included the economic repercussions of the COVID-19 pandemic, the Russia-Ukraine conflict, energy shortages, labour constraints, and, most notably, disruptions in global supply chains. While this policy primarily addressed import costs, it did little to reduce import volumes. Edible oil imports increased from 156 lakh tonnes in 2019 to 162 lakh tonnes in 2023, highlighting India's sustained dependence on key suppliers like Indonesia, Malaysia, Argentina, and Brazil. This reliance underscores the critical role of imports in meeting the nutritional needs of India's vast population while reflecting a persistent rise in consumer demand. The growing share of imports in total edible oil consumption underscores both the challenges of domestic production shortfalls and the increasing pressures of a steadily expanding and evolving consumer base. In parallel, the exporting nations have effectively utilised their agricultural resources to address energy crises by nurturing a biofuel ecosystem. All these developments assume that demand and supply side changes affect market dynamism (Ewing and

Msangi, 2009; Enciso et al., 2016; Boly and Sanou, 2022; Chakravorty et al. 2019) for an importing country like India, as the diversion of edible oilseeds to biofuel production exacerbates the flow of persistent increase in imports, which in turn, raises concerns about the domestic supply of staple foods such as edible oil.

On the other hand, the incessant increase in imports also underscores the country's inability to meet the necessary demand for edible oils through domestic production and dependency on imports. To address challenges in edible oil availability, the Indian government launched initiatives like the National Food Security Act 2013, the Public Distribution System, and the Minimum Support Price scheme, prioritising higher minimum support prices (MSPs) for oilseeds to promote diversification in agriculture. India has remarkably increased its oilseed output nearly sevenfold since independence, reaching 35.94 million tonnes in 2020-21 however, given the fact that ever-bourgeoning population, rising per capita income, urbanisation and changing food habits, there always have been a disequilibrium in demand and supply in post liberalised era. The market dynamics of India's edible oil can be understood by the fact that India produces a mere 40% of total consumption requirements and is heavily dependent on imports.

Figure 1:
Status of Import of Edible Oil by India

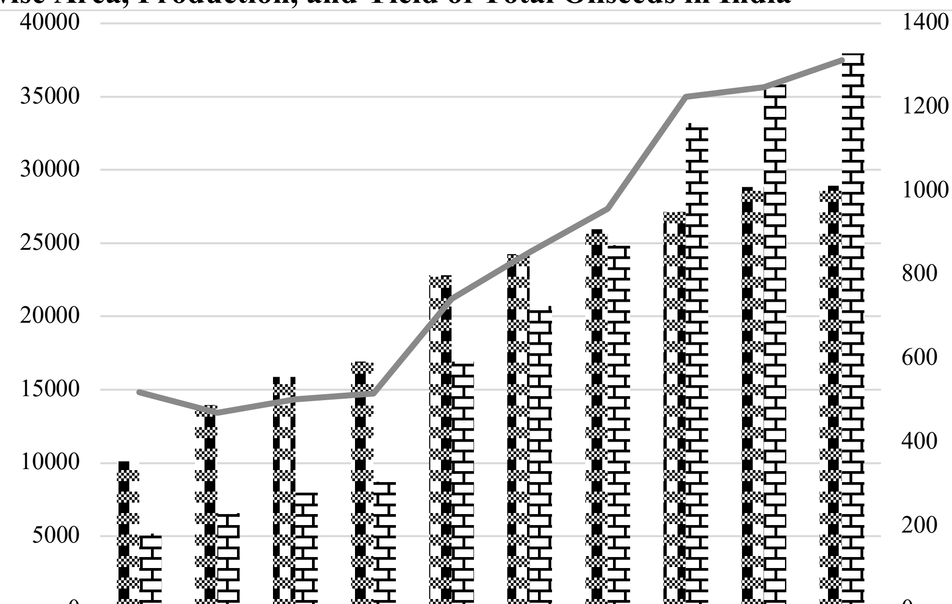


Source: UN-Comtrade, accessed at ITC-Trademap

Socio-economically, edible oils constitute a fundamental element of Indian cuisine and find application in diverse industrial sectors, encompassing pharmaceuticals, cosmetics, and biofuel production (Gaur et al., 2022). Additionally, agro-industrial by-products like residual oilseed cakes and meals derived from oil extraction serve as elemental protein ingredients in animal feed, notably replacing fish meal in poultry, pig, and aquatic animal diets (Duodu et al., 2018). Culinary-wise, edible oils play integral roles across India's diverse regional cuisines: mustard predominates in the north and east, soybean in central and southeast regions, peanut oil in the west, and coconut oil in southern dishes, each contributing unique flavours and nutritional benefits. Rich in fatty acids necessary for hormone synthesis (Song et al., 2021), brain function (J. B. S. Kumar and Sharma, 2022), and cellular growth (Taniguchi et al., 2003), these oils support vital physiological processes. With an energy density of approximately nine calories per gram, they serve as efficient energy sources and facilitate the absorption of fat-soluble vitamins (A, D, E, and K) essential for vision, immunity, and skeletal integrity. Optimal cardiovascular health is promoted by oils abundant in monounsaturated and polyunsaturated fats; olive, canola, and mustard oils are rich in monounsaturated fats, while soybean and sunflower oils contain ample polyunsaturated fats, particularly linoleic acid (M. Sharma et al., 2016). India's status as the most populous country, coupled with evolving dietary preferences towards processed foods like cheese, mayonnaise, margarine, and snacks, alongside increasing incomes, has intensified domestic demand for edible oils. This surge in demand comprises domestic consumption, animal feed requirements, and industrial uses, highlighting the linchpin role of edible oils in India's socio-economic landscape.

To address the burgeoning demand, the government has implemented various strategies. These initiatives have resulted in a modest, yet noteworthy, increase of 2.87 times in India's area sown for oilseeds. Furthermore, between 1949 and 2021, domestic oilseed production has been a sevenfold increase. Conversely, yield has only increased by 2.53 times, indicating concerns about agricultural productivity and efficiency in oilseed supply (Figure 2).

Figure 2:
Season-wise Area, Production, and Yield of Total Oilseeds in India



	1949-1950	1959-1960	1969-1970	1979-1980	1989-1990	1999-2000	2009-2010	2019-2020	2020-2021	2021-2022
Area(In '000 Hectare)	10100	13950	15874	16941	22800	24258	25959	27139	28834	28945
Production(In '000 Tonne)	5200	6560	7975	8739	16924	20710	24882	33219	35946	37963
Yield(In Kg./Hectare)	519	470	502	516	742	854	958	1224	1247	1312

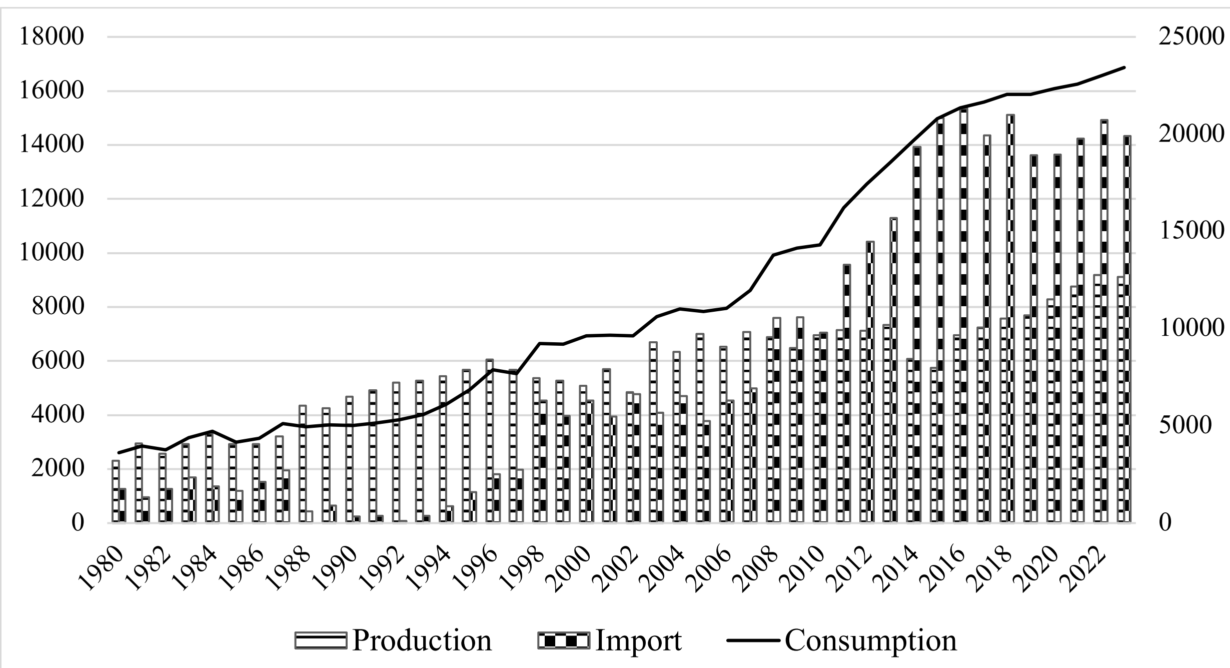
Source: Ministry of Agriculture & Farmers Welfare, Govt. of India

India initiated the 'Yellow Revolution' to boost edible oil production, achieving self-sufficiency by the early 1990s. This success transformed India from a net oilseed importer in the 1980s to a net exporter (Kumar and Tiwari, 2020). However, opening the Indian economy and liberalising tariff and trade policies in the 1990s led to increased reliance on imports (Chakraborty and Maitra, 2021;

Ghosh N, 2009). The liberal trade and tariff policies facilitated the cheap import of palm, soybean, and sunflower oil, leading to monumental import dependency by 1997-98—subsequent policy interventions needed to sufficiently enhance domestic production, resulting in unsustainable import levels by 2018(Ghosh N, 2009). A dynamic policy shift occurred in 1994 when the Indian government liberalised tariff, trade, and regulatory policies for edible oils, categorising edible vegetable palmolein under an 'open general license' (OGL) to meet growing consumer demand. The low prices of palm oil in India's price-sensitive market, further tariff liberalisations, and changing consumer preferences led to increased edible oil imports to meet domestic needs. From 2009 to 2019, India's edible oil consumption rose from 14 million tonnes to approximately 20 million tonnes, with imports constituting about 60% of total demand. In the fiscal year 2022-2023, India imported approximately 8.3 million metric tonnes (MMT) of palm oil, 5.4 MMT of soybean oil, and 3.6 MMT of rapeseed oil, representing 98% of the country's total edible oil imports [1]. More importantly, it is estimated that domestic sources and imports collectively fulfil approximately 86% of the demand, leaving a deficit of 14%, gravely underscoring the prevailing issue of food insecurity within India (Figure 3).

Figure 3:

Increasing Vulnerability to the Supply-Demand Dynamics (000' MT)



Source: IndexMundi

A major gap exists between the Supply and Demand of indispensable goods, prompting the government to liberalise import policies to ensure supply in the domestic market. While this approach ensures short-term supply and fulfils domestic demand, it strains foreign exchange reserves due to the high volume of imports. To address this, the government prioritises boosting domestic oilseed production and reducing import dependence. Therefore, the Government of India has initiated multiple strategies, such as the Technology Mission on Oilseeds, which substantially expanded the oilseed cultivation area from 9 million tons in 1986 to 32 million tons in 2018-19. Additionally, the National Mission on Oilseeds & Oil Palm (NMOOP), initiated in the fiscal year

[1] https://www.statista.com

2014-15 and operational through 2017-18, represents a strategic effort to decrease reliance on imported edible oils, particularly palm oil[2]. A pivotal development in this initiative occurred on November 29, 2017, with the integration of NMOOP into the restructured National Food Security Mission (NFSM), now termed NFSM-Oilseeds & Oil Palm. This scheme aims to escalate oil palm cultivation to 10 lakh hectares by 2025-26, up from 3.5 lakh hectares in 2019-20, targeting a production of 66.00 lakh tonnes of Fresh Fruit Bunches (FFBs). Jat et al. (2019) examined India's efforts to reduce edible oil imports and increase oilseed acreage and production activities, estimating that 39.2 million tonnes of edible oil will be needed in 2050 to meet the target population of 1.68 billion people at a consumption level of 37 kg/head/year.

However, achieving this goal necessitates navigating challenges associated with demand-supply dynamics, which are imperative to understand. These challenges include price fluctuations, hoarding, inflationary pressures, and food justice issues like malnutrition and adulteration. Additionally, volatility in global edible oil prices directly impacts affordability, particularly for low-income households, potentially leading to economic instability and public health concerns.

This study employs a two-step approach to analyse the demand-supply relationship. The Principal Component Analysis (PCA) was employed to construct Demand and Supply indices, capturing the underlying dynamics within each subsystem reducing data dimensionality, and retaining the original data's variance by transforming the original correlated variables into a smaller set of uncorrelated principal components (Pearson,1901; Hotelling, 1933) and then applies VECM techniques to explore the relationship among primarily developed indices for different subsystems (Lafi and Kaneene, 1992), as PCA limitations prevent direct observation of short-run interactions and long-run equilibrium between these subsystems. To address this, a Vector Error Correction Model (VECM) is utilised, particularly to analyse cointegrated variables, where non-stationary variables maintain a long-run equilibrium relationship (Davidson, 2013). By employing a VECM, we can delve into the short-run dynamics and long-run equilibrium behaviour, as well as the speed of error correction between the Demand and Supply indices.

This Paper addresses these research questions:

1. How can indices be constructed to analyse and decompose the underlying determinants of the Demand and Supply sub-systems in the edible oil market?
2. What is the relationship between these sub-systems?
3. How can the market attain self-sufficiency in the edible oil market?

II. DATA AND METHODOLOGY

Our dataset comprises time series data on various factors influencing the edible oil market from 1981 to 2021, sourced from the Indexmundi[3] database and International Trade Map[4], with population and income data from the World Bank[5]. We have taken into account the data of appropriate edible oils, including oil meal and oilseeds, playing a large role in the edible oil market in India (Table 1).

Table 1:

[2] https://nmeo.dac.gov.in
[3] https://www.indexmundi.com
[4] https://www.trademap.org
[5] https://data.worldbank.org

Beginning Stock	Coconut	Cotton	Palm	Peanut	Rapeseed	Soyabean	Sunflower	
Ending Stock	Coconut	Cottonseed	Palm oil	Peanut oil	Rapeseed	Soybean		
Import	Coconut	Soyabean	Peanut	Palm	Sunflower	Rapeseed	Other oil	
Production	Coconut	Copra	Cotton	Palm	Peanut	Rapeseed	Soybean	Sunflower
Crush	Cotton	Peanut	Rapeseed	Coconut	Soybean	Sunflower		
Domestic Consumption	Coconut	Cotton	Palm	Peanut	Rapeseed	Soyabean	Sunflower	
Animal Feed Waste	Copra	Cotton	Peanut	Rapeseed	Soybean			
Processing Food Industries	Coconut	Cotton	Palm	Peanut	Rapeseed	Soybean		
Non-Food Industries Consumption	Coconut	Cotton	Palm	Rapeseed				

Source: Index Mundi and International Trade Map

Furthermore, we have considered data on variables prominent to domestic supply parameters as well as imports, an external supply factor and determinants influencing demand in the domestic market. Consequently, we have included variables such as population, income, imports, beginning stock, production, domestic consumption, waste used as animal feed, food uses in the processing industry, industrial consumption (e.g., pharmaceuticals, cosmetics), ending stock, and crush (Table 2). The variables used to characterise the different subsystems within this study are determined by two primary considerations: the underlying theoretical foundation and the availability of relevant data.

Table 2:

Variables for Demand and Supply

Sub-systems	Demand Index	Supply Index
Variables	P_O: Population	P_R: Production
	I_N: Income	B_S: Beginning Stock
	D_C: Domestic Consumption	E_S: Ending Stock
	A_F: Waste Animal feed (AF)	C: Crush
	F_I: Used in Processing Food Industries	I_M: Import
	I_C: Industrial Consumption (IC)	

A. PRINCIPAL COMPONENT ANALYSIS

Principal Component Analysis (PCA) is a well-established statistical technique employed to analyse and interpret datasets with interrelated variables (Vyas & Kumaranayake, 2006). In this study, PCA is utilised to address the challenge of high dimensionality in the Indian edible oil market data, characterised by original variables (X1, X2, X3, X4). PCA effectively reduces dimensionality by creating new uncorrelated variables called principal components (PCs) that capture the most substantial variance in the original data. A fundamental prerequisite for successful

PCA application is that the original variables exhibit some degree of correlation. The application of PCA in this study resulted in two principal components: Demand Index (DI) and Supply Index (SI). As shown in Figure 4, these indices exhibit a perfect positive correlation. This strong positive correlation evidences a close relationship between the factors influencing demand and supply in the Indian edible oil market.

The values of Demand Index and Supply Index can be calculated using the weight matrix (W) and the following equations:

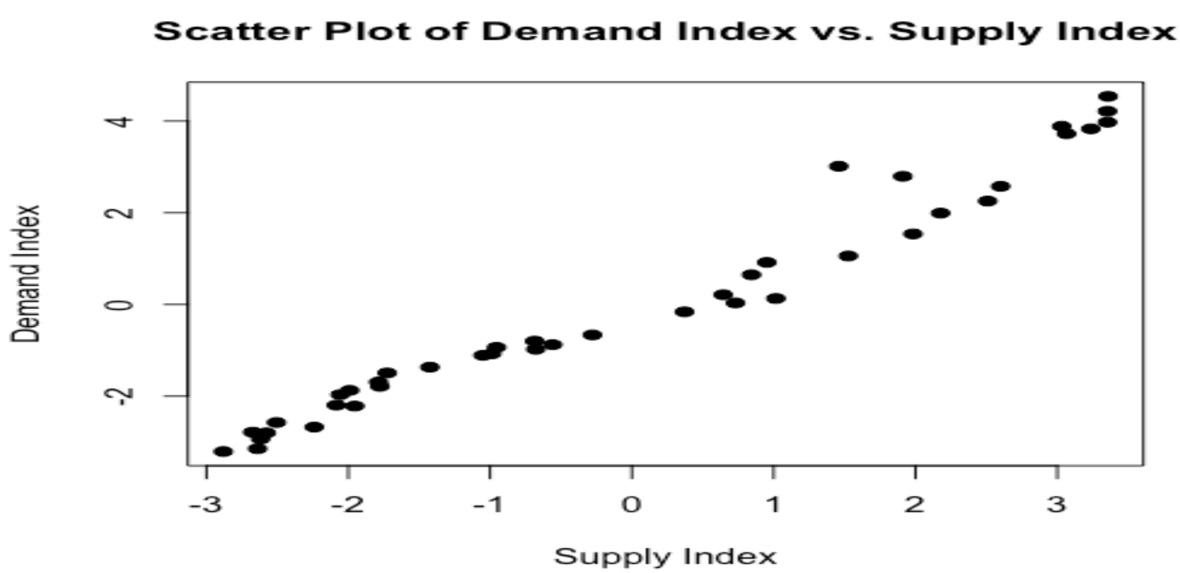
Demand Index (DI) = $\Sigma W_i * X_i$ (i= 1 to n_demand) --(1)
Supply Index (SI) = $\Sigma W_i * X_i$ (i= 1 to n_Supply) ---(2)

Here,

- W_i denotes the weight for the i^{th} variable in the weight matrix (specific to demand or supply).
- X_i represents the i^{th} original variable used in the PCA (either demand-side or supply-side).
- n_demand and n_supply represent the total number of variables used to calculate the Demand Index and Supply Index, respectively.
- The sigma (Σ) symbol signifies summation across all relevant variables (i) for demand or supply.

Figure 4:

Correlation between Demand and Supply Indices



B. VECTOR CORRECTION MODEL

The PCA step identified the weightiest underlying factors within each Sub-system. These factors, captured by the principal components, become the variables used in the subsequent VECM analysis. The Vector Error Correction Model (VECM) is a sophisticated tool for time series analysis, adept at handling situations where multiple variables dynamically influence each other. It is particularly valuable when these variables exhibit a cointegrated relationship, indicating a tendency to move together in the long run despite short-term fluctuations. VECMs effectively capture the short-term impacts, such as how a sudden decrease in supply might immediately increase demand. Beyond addressing short-run variations, VECMs incorporate a "long-run memory," ensuring variables gravitate towards a stable equilibrium over time. This is facilitated by an "error correction term," which penalises deviations from this equilibrium, thus promoting long-term stability. The Vector Error Correction Model (VECM) captures short-term and long-term dynamics. Equation (3) and (4) gives the condensed form of the VEC model of the study for Demand index and Supply Index respectively

Demand Index

$$\Delta DI_t=\alpha+\lambda ECT_{t-1}+\sum_{j=1}^{p}\beta_j\Delta DI_{t-j}+\sum_{j=1}^{p}\gamma_j\Delta SI_{t-j}+\epsilon_t. \quad (3)$$

Supply Index

$$\Delta SI_t=\alpha+\lambda' ECT_{t-1}+\sum_{j=1}^{p}\beta_j'\Delta DI_{t-j}+\sum_{j=1}^{p}\gamma_j'\Delta SI_{t-j}+\nu_t \quad (4)$$

- ΔDI_t and ΔSI_t represent the first differences of the indices.
- ECT_{t-1} is the Error Correction Term, adjusting the model toward equilibrium.
- β_j, γ_j, β_j' and γ_j' are short-run coefficients capturing lag effects.
- ϵ_t and ν_t are white noise error terms.
- λ and λ' measure the speed of correction toward equilibrium.

III. RESULT AND FINDINGS:

This section details the construction of two separate indices, one for the Demand Index and one for the Supply Index, using Principal Component Analysis (PCA). Since these indices represent combinations of variables within each subsystem, they are likely to capture the underlying dynamics of the system.

A. DEMAND SUBSYSTEM (DI)

The six variables from Table 3 are used to construct the demand sub-system, denoted as DI in this paper and Table 3 shows the eigenvalue of the sub-system Demand Index.

Table 3:

Estimation of Eigen Value of Demand Index

Principal Components	Eigenvalue	Proportion	Cumulative	Difference
1	5.66	0.94	0.94	5.66
2	0.19	0.03	0.97	-5.46
3	0.09	0.01	0.99	-0.09
4	0.03	0.00	0.99	-0.06

5	0.01	0.00	0.99	-0.02
6	0.00	0.00	1.00	-0.00

The PCA identified the principal component (PC1) with the highest eigenvalue (5.6643), capturing 94.4% of the variance in the demand-side data for India's edible oil market. The scree plot (Figure 5) supports PC1 as sufficient for analysing the demand subsystem, with results summarised in Table 4.

Figure 5:

Schematic view of Eigenvalues of Demand Sub-system

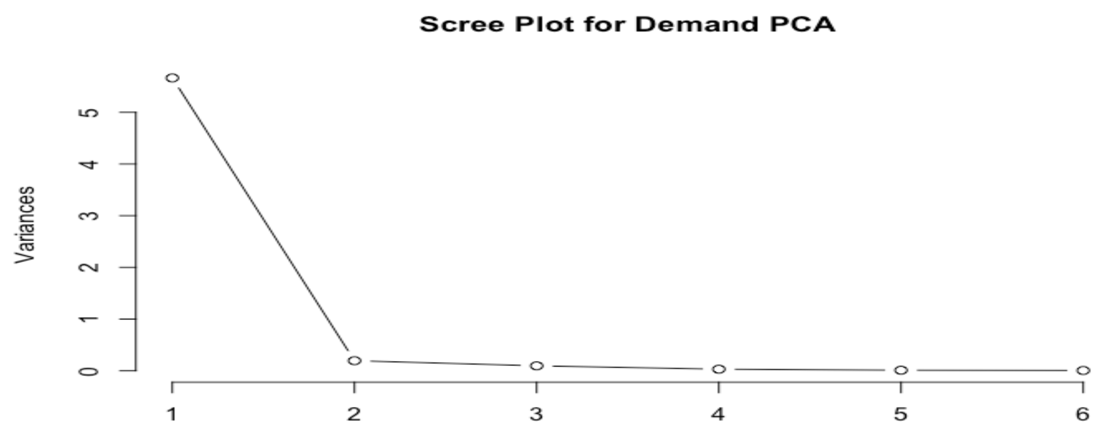


Table 4:

Estimation of Coefficients for the Principal Component of the Demand Subsystem

VARIABLES	PC1	PC2	PC3	PC4	PC5	PC6
P_O	0.408	-0.299	0.569	-0.381	0.193	-0.486
I_N	0.408	0.131	-0.694	-0.269	0.490	-0.143
D_C	0.412	-0.374	0.162	0.269	0.337	0.690
A_F	0.413	-0.243	-0.218	0.655	-0.350	-0.412
F_I	0.417	0.001	-0.121	-0.482	-0.695	0.308
I_C	0.388	0.832	0.323	0.218	0.0427	0.037

The Principal Component Analysis (PCA) indicates the correlations of variables with the first principal component (PC1) in the demand index (DI) for India's edible oil market, ranked from highest to lowest as follows: Processed Food Industries (F_I), Waste Animal Feed (A_F), Domestic Consumption (D_C), Income (I_N), Population (P_O), and Industrial Consumption (I_C). The normalised coefficients reflect each variable's relative significance. Equation (5) captures the linear combination of these variables, revealing that the food industry significantly influences the DI, followed closely by waste animal feed and domestic consumption (Shroff, Shah and Kundurthi, 2024). Conversely, income, population growth, and industrial consumption exert lesser effects.

Demand Index (PC1) = 0.408 * P_o + 0.408 * I + 0.412 * D_C + 0.413 * A_F + 0.417* F_I + 0.388 * I_C ------------------------Equation (5)

B. SUPPLY SUBSYSTEM (SI)

The eigenvalue analysis for the supply subsystem (Table 5) identifies the first principal component (PC1) as dominant, with an eigenvalue exceeding one and explaining 87.83% of the total variance. The Scree plot (Figure 6) supports this, showing a sharp decline after PC1, indicating its sufficiency for significant economic analysis.

Table 5:

Estimation of Eigen Value of Supply

Principal Components	Eigenvalue	Proportion	Cumulative	Difference
1	4.39	0.87	0.87	4.39
2	0.41	0.08	0.96	-3.97
3	0.10	0.02	0.98	-0.31
4	0.08	0.02	0.99	-0.02
5	0.00	0.00	1.00	-0.08

Figure 6:

Schematic view of Eigenvalues of Supply Sub-system

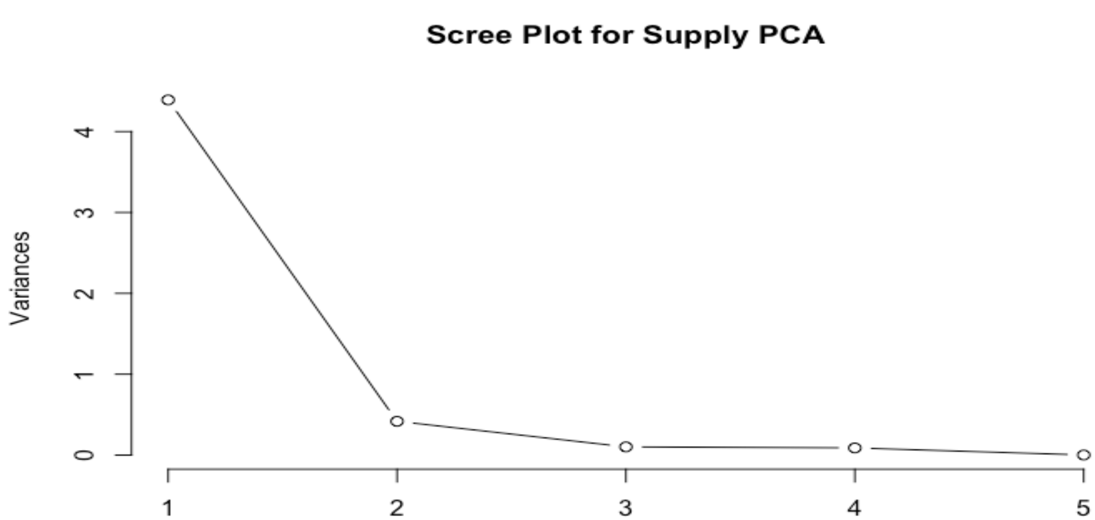


Table 6 displays the factor loadings for the five principal components in the supply subsystem, highlighting the influence of each variable. Ending Stock (E_S) has the highest loading on PC1, followed by Production (P_R), Beginning Stock (B_S), Crush (C), and Import (I_M), underscoring their strong contributions to PC1.

Table 6:

Estimation of Coefficients for the Principal Component of the Supply Subsystem

Variables	PC1	PC2	PC3	PC4	PC5
I_M	0.441	0.463	-0.587	-0.495	0.008
B_S	0.446	0.406	-0.017	0.795	-0.047
P_R	0.451	-0.499	-0.029	-0.043	-0.737
E_S	0.455	0.206	0.788	-0.335	0.126
C	0.442	-0.573	-0.177	0.080	0.662

Equation (6) expresses PC1 as a linear combination of the original supply variables drawing upon the factor loadings in Table 7. The Equation highlights the weights (coefficients) associated with each variable in their contribution to the Supply Index:

Supply Index (PC1) = $0.441 * I_M + 0.446 * B_S + 0.451 * P_R + 0.455 * E_S + 0.442 * C$ ---Equation (6)

Table 6 and Equation (6) highlight that maintaining a stable edible oil supply in India requires balancing multiple factors within the Supply Index. Key drivers include imports, production, and stock levels. Higher beginning stocks can offer temporary relief by reducing import needs, while higher ending stocks support supply continuity. Domestic oilseed processing, or crush activity, also boosts the Index. India's high import coefficient reflects a strong reliance on imports to meet demand. Before applying the Vector Error Correction Model (VECM), the study performs the Augmented Dickey-Fuller (ADF) test to confirm the stationarity of the Demand and Supply Indices under three scenarios: with intercept and trend, with intercept only and without intercept or trend (Table 7).

Table 7:

Results of ADF Unit Root Test

	With Intercept and Trend		With Intercept and Without Trend		Without Trend and Intercept	
	T- Statistics	P-value	T- Statistics	P-value	T- Statistics	P-value
Demand Index	-1.23	0.26	1.30	0.44	0.43	0.02
Supply Index	-3.65	0.00	-0.31	0.84	-0.43	0.86

Demand Index Diff	-5.26	0.00	-4.65	0.00	-2.24	0.00
Supply Index Diff	-6.11	0.00	-6.14	0.00	-4.79	0.00

Data is differenced to ensure stationarity, and at first-order stationarity I (1), it has been confirmed stationarity across all scenarios. The Lag 1 at Johansen Cointegration Test (Table 8) reveals long-term equilibrium, justifying the Vector Error Correction Model to capture both short-term and long-term relationships for robust results(Clive W.J. Granger and Cointegration, 2017; Davidson, 2013).

Table 8:

Cointegration Test

Coefficients	**Estimate**	**Std. Error**	**t value**	**P- value**
z.lag.1	-0.31	0.13	-2.37	0.02
z.diff.lag	0.16	0.17	0.94	0.35

C. FINDINGS OF THE VCE MODEL

The Vector Error Correction Model (VECM) identifies a long-term equilibrium relationship between the Demand Index (DI) and Supply Index (SI), where a unit increase in DI corresponds to a 1.22-unit decrease in SI, restoring balance over time. This relationship can be expressed as:

DI+(-1.22) × SI = Constant ----------------------------(7)

Negative Error Correction Terms indicate that 57.02% and 68.23% of disequilibria in DI and SI(Table 9), respectively, are corrected each period, with SI influencing DI up to six lags after performing the Information Criteria Test.

$\Delta DI_t = -0.57ECT_{t-1} + 0.69I + 0.38\Delta DI_{(t-1)} - 1.05\Delta SI_{(t-1)} - 0.10\Delta DI_{(t-2)} - 0.63\Delta SI_{(t-2)} + 0.59\Delta DI_{(t-3)} - 1.10\Delta SI_{(t-3)} - 0.13\Delta DI_{(t-4)} - 0.57\Delta SI_{(t-4)} - 0.13\Delta DI_{(t-5)} - 0.37\Delta SI_{(t-5)} + 0.37\Delta DI_{(t-6)} - 0.63\Delta SI_{(t-6)}$ ---------------(8)

$\Delta SI_t = -0.68ECT_{t-1} + 1.058I + 0.63\Delta DI_{(t-1)} - 1.36\Delta SI_{(t-1)} - 0.06\Delta DI_{(t-2)} - 1.12\Delta SI_{(t-2)} + 0.32\Delta DI_{(t-3)} - 1.54\Delta SI_{(t-3)} - 1.20\Delta DI_{(t-4)} - 0.63\Delta SI_{(t-4)} + 0.63\Delta DI_{(t-5)} - 1.16\Delta SI_{(t-5)} + 0.54\Delta DI_{(t-6)} - 0.80\Delta SI_{(t-6)}$ ----(9)

Table 9 :

Output of VECM model

	DI Co-efficient(p-value)	**SI Co-efficient(p-value)**

Error Correction Term (E)	-0.57(0.10) ***	-0.68(0.26) *
Intercept (I)	0.69(0.11) ***	1.05(0.27) **
DI (t-1)	0.38(0.19)	0.63(0.48)
SI (t-1)	-1.05(0.17) ***	-1.36(0.42) **
DI (t -2)	-0.10(0.1881)	-0.06(0.46)
SI (t-2)	-0.63(0.15) ***	-1.12(0.36) **
DI (t-3)	0.59(0.21) *	0.32(0.52)
SI (t -3)	-1.10(0.15) ***	-1.54(0.39) ***
DI (t-4)	-0.13(0.21)	-1.20(0.53) *
SI (t-4)	-0.57(0.17) **	-0.63(0.43)
DI (t-5)	-0.13(0.25)	0.63(0.62)
SI (t-5)	-0.37(0.13) *	-1.16(0.33) **
DI (t-6)	0.37(0.24)	0.54(0.60)
SI (t-6)	-0.63(0.17) **	-0.80(0.43)

D. MODEL VALIDITY

Diagnostic tests confirm the VECM model's validity (Table 10). The Portmanteau test (p=0.14) shows no residual autocorrelation, while the ARCH test (p =1) indicates no heteroskedasticity. The JB test (p=0.58), alongside skewness and kurtosis results, supports normality, symmetry, and mesokurtic distribution of residuals.

Table 10:

Diagnostic Tests

	Chi-squared	Df	P-value
Portmanteau test	69.51	58	0.14
Arch (multivariate)	66	144	1
Jb-test (multivariate)	2.86	4	0.58
Skewness only (multivariate)	0.15	2	0.93
Kurtosis only (multivariate)	2.71	2	0.26

E. CONCEPTUAL IMPLICATIONS:

The PCA-VEC model offers a comprehensive analysis of the demand and supply dynamics in India's edible oil market. A pivotal insight is the influence of surplus ending stocks, a key driver of the Supply Index, which includes both domestic production and imports. With imports significantly outpacing domestic production, stockpiling leads to lower prices, fuelling demand across sectors like processed foods, animal feed, and household consumption. This surplus not only drives industrial innovation and product diversification but also enhances market reach. Particularly, ending stocks from as far back as six years play a critical role in shaping current demand, primarily driven by industrial needs, the finding that aligns with previous studies (Chakraborty & Maitra, 2021).

However, this abundance poses challenges for domestic producers. Low-cost imported oil undermines the profitability of oilseed farming, despite the availability of minimum support prices (MSPs). A lack of trust in government procurement mechanisms exacerbates this issue, further discouraging local production. Over the past five years, domestic production has consistently lagged behind the growing demands of processing industries, animal feed sectors, and households, worsening supply deficits and limiting self-sufficiency.

To bridge these gaps, the government has relied on liberalised import policies. While these measures address immediate demand and stabilise prices in the domestic market, they reinforce a dependency on cheap imports, creating vulnerabilities to global price volatility and supply chain disruptions. This reliance stifles domestic production, making the market increasingly susceptible to external shocks, as highlighted in earlier research (Meena & Khorajiya, 2016).

The VEC model's error correction terms provide valuable insights into market adjustment mechanisms. Approximately 57% of demand imbalances and 68% of supply disequilibrium are corrected within each period, with the market achieving stability in three to five years after a shock.

while import liberalisation offers short-term relief, it entrenches long-term vulnerabilities. Addressing these requires a strategic overhaul, including robust incentives for domestic production, improved supply chain infrastructure, and restoring trust in procurement mechanisms. By breaking the cycle of dependency, India can build a resilient and self-sufficient edible oil market, safeguarding affordability, and mitigating risks from global shocks—a transformative step toward sustainable growth and food security.

IV. CONCLUSION AND POLICY RECOMMENDATIONS:

India's edible oil sector requires robust policy interventions to enhance domestic production and reduce import reliance. Insights from the PCA-VEC model suggest that the demand-supply gap stabilises within 3–5 years, necessitating synchronised reforms on both sides. Providing high-quality seeds is crucial for improving yields on limited arable land (Cui et al., 2022). Additionally, guaranteed procurement policies and fair Minimum Support Prices (MSP) can increase farmer confidence and investment in oilseed cultivation (Gulati et al., 2019). Gradually increasing import duties on edible oils, alongside investing in research for improved oilseed varieties, will further support sustainability and market stability (Abokyi and Asiedu, 2021).

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