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Studies on the effectiveness of milk vendorship in Uttar Pradesh: A principal component analysis approach

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ABSTRACT

This study was conducted to analyze the effectiveness of milk vendorship in Uttar Pradesh by using multistage random sampling across the Eastern, Central, Western and Bundelkhand economic regions. Data were collected from the selected120 milk vendors of the towns vendors who had been in the dairy venture for at least five years i.e. 2015-16 to 2020-21 through structured interview schedule. The collected data focused on major effectiveness indicators such as income generation, operational efficiency, infrastructure facilities, and competitiveness. Employing Principal Component Analysis (PCA), objective weights were given to these indicators, and a holistic effectiveness index was developed. The findings showed that the major dimensions influencing vendorship effectiveness were competitiveness (19.697), followed by income generation (15.473), operational efficiency (12.462), and infrastructure facilities (10.201). The findings indicated that only 30.80 percent of vendors were highly effective, 32.5 per cent were medium, and 36.7 per cent were low. Vendors with medium and high-effectiveness level benefited relatively more due to reduced cost family labour and integration of technologies. Strengthening vendor capacities through government initiatives, need-based training, and mechanization assistance could optimize vendorship, ensuring the distribution of high-quality milk, increased income, and resistance to market fluctuations, ultimately leading to a sustainable dairy economy.

Keywords: Dairying practices, Effectiveness index, Milk marketing, Milk vendorship, PCA, Sustainable dairying

India's dairy industry has grown remarkably over the last ten years. From 146.30 million tonnes in 2014–15 to 239.30 million tonnes in 2023–24, milk production increased by 63.56 per cent and sustained a remarkable 5.7 per cent annual growth rate for the last ten years (NDDB 2023, DAH&D 2024). For several years, India has been the world's top producer of milk, accounting for around 25 per cent of worldwide production. In India, the quantity of milk availability per person has increased substantially in the last ten years. In 2023–2024, the per capita availability increased by 48 per cent to exceed 471 grams per person per day, significantly more than the global average, 351 grams per person per day (DAH&D, 2024). Uttar Pradesh is one of the major contributors to this dairy sector and a substantial player in India's dairy sector. This state is widely renowned as the homeland of *Dhudiyas* (milk vendors) and the source of a small number of private dairy producers (Dixit and Ponnusamy, 2022a). The state recorded highest milk production in India, with an annual production of 38 million metric tons in 2023–24 (DAHD&F, 2024). It is home to the highest number of buffalo and second-highest number of cattle in India (Behl *et al.* 2024). The state's per capita availability of milk is 450 gms/day, which is somewhat lower in comparison to the national average. It contributes around 16.21 percent of the country's total milk production. The dairy industry in Uttar Pradesh is vital to regional agricultural development since it boosts household earnings and the state's rural economy (Dixit and Ponnusamy, 2022b). Despite this achievement, the dairy sector remains mainly unorganized, especially at the grassroots level, where milk vendors play a crucial role as intermediaries between producers and customers (Ponnusamy *et al.* 2021). The unorganized sector generates and handles the remaining 80% of India's milk, with only 20% being handled by an organized sector. (Ponnusamy *et al.* 2020). Given the significance of milk vendorship in the state's milk supply chain, understanding the effectiveness of vendorship operating in state is inevitable for improving dairy productivity, product quality, and market competitiveness (Thakur *et al.* 2021). This study was intended to measure the multifaceted role and operational efficiency of milk vendorship in Uttar Pradesh in order to analyze the effectiveness of milk vendorship.

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MATERIALS AND METHODS

Selection of study area: To assess the effectiveness of milk vendorship this study was undertaken in four distinct regions of Uttar Pradesh. The state is divided into 75 districts, which were classified in four economic regions, namely Eastern U.P., Central U.P., Western U.P., and the Bundelkhand region. The multistage random sampling method was employed for selecting the state, districts, blocks, towns, and ultimately vendors from the study area. One district from each region, namely Ayodhya, Lucknow, Meerut, and Banda, which represented four regions of Uttar Pradesh.

Eastern Uttar Pradesh is characterized by fertile plains, and relies mostly on conventional agriculture and small-scale dairying. Central Uttar Pradesh, which is developed with features such as strong milk vendorship networks, developed markets, and commercial activities. Western Uttar Pradesh is well-known for its commercial agriculture and close proximity to national capital, while the Bundelkhand region of Uttar Pradesh, has a limited access to markets and agriculture outputs, which its affects milk vendorship. On the basis of above factors, the experimental districts were chosen. One block was randomly chosen from each of the following districts: Atarra in Banda District, Daurala in Meerut District, Malihabad in Lucknow District, and Rudauli in Ayodhya District. Within each selected block, a settlement representing peri-urban characteristics was chosen. Almost all selected blocks represented these characteristics. From each selected town, thirty milk vendors, who had been actively engaged in milk selling for at least five consecutive years, were randomly chosen.

Data collection: The study was carried out using a survey research design, and the primary data was collected through the interaction with the respondents. For evaluating vendorship effectiveness, first four major dimensions were taken such as Income Generation (IGI), Operational Efficiency (OEI), Infrastructure Facilities (IFI), and Competitiveness (CI). These dimensions included 21 indicators, as delineated in Table 1. The IGI dimension comprised of five indicators: milk sold per day (liters), average sale price, gross income per day, average cost, and net returns per day. The OEI dimension involved four indicators: time gap in delivery, customers served per day, distance covered per day, and time taken per client. The IFI dimension comprised of five indicators: distribution logistics, ownership status, utilization percentage, milk quality testing, and milking machine use. The ability to evaluate market competitiveness, price in relation to the market, a diverse product portfolio, innovativeness, advertising, the use of virtual platforms, and risk management in unexpected situations were the seven indicators that covered in the CI dimension.

Parameters recorded/studied: The following parameters were recorded for the above study through structured questionnaire.

MSD is the average milk quantity sold by the vendors per day in liters; ASP is the average price per unit of milk sold by the vendors to customers; GID is the average total income earned from milk sales per day in rupees; AVC is the average total cost incurred by the vendors while collecting the milk from producers and the travelling cost per day; NRD is the amount of money earned by the vendors in selling the milk; TG is the average time difference in distributing milk to each customer, and CSD is the average total number of customers served by the vendor per day. DCD is the distance in kilometers covered by the vendors in milk distribution; TTC is the average time in minutes taken by the vendor in milk distribution per client; DLG is measured as up to what extent the normal or cold chain (bulk milk cooler, deep freezer, and refrigerator) is used; OWN is the ownership status of resources (own or rental); UTP is the total quantity of milk sold and quantity held for own use; MQT is measured as the frequency of milk testing in number of times per week; MMN is the total number of vendors who adopted machine as a milking method; AMC is the total number of vendors who have the idea to analyze the competition in the market; PCM is the difference in price of milk as compared to the market (more or less); DPP is the total quantity of milk used for preparing different milk products; INV is the total number of milk products (khoa, paneer) offered by vendors, in addition to raw milk; ADV is the total number of vendors engaged in brand building for selling their produce; VPL is the total number of vendors using a virtual platform in transactions and getting quick information related to the venture, and RHUC is the total number of vendors who have the ability to efficiently handle the milk during unforeseen circumstances.

Statistical analysis: Collected data were tabulated and normalized to warrant comparability across various measurement scales. Normalization of the indicators was done in order to ensure that all the indicators were comparable owing to measurement on various scales for each indicator (Feroze and Chauhan 2010, Ayyoob *et al.* 2013, and Ponnusamy *et al.* 2016). For the indicators that have a positive functional relationship with their corresponding index, the normalization was done employing the following equations:

For positive functional relationship:

$$\text{Normalization} = \frac{\text{(Actual value-Minimum value of data)}}{\text{(Maximum value-Minimum value of data)}}$$

For negative functional relationship:

$$\text{Normalization} = \frac{\text{(Maximum value-Actual value of data)}}{\text{Maximum value-Minimum value of data}}$$

Assignment of appropriate weights to be applied to various indicators:After the scale bias was eliminated from the observations, the chosen indicators were assignedappropriate weights. Assigning arbitrary weights that are based on personal judgment is subjective and should only be considered as a last option. Therefore, in

this study, the weights of each individual indicator were objectively assigned using PCA (Principal Components Analysis). PCA is one of the techniques of reducing the dimensionality of data which increases the interpretability while minimizing loss of information. It does so by generating new uncorrelated variables that progressively increase variance, and it is also adaptive in another way as it simplifies to solve an eigenvalue, to find such new variables, the principle components, and because the new variables are defined by the dataset in question rather than a priori. PCA was applied using the Statistical Package for Social Sciences (SPSS version 20 for Windows).

Eigenvalues and factor loadings were computed by PCA using SPSS (version 20). Based on the number of eigenvalues greater than one, the same numbers of components are taken out of the rotational component matrix for each variable. The eigenvalues are then multiplied by the retrieved component matrix. This is accomplished by multiplying the first Eigen Value by the first extracted component column, followed by the second Eigen Value by the second extracted component column, and so on. The weight of each indicator is calculated by adding up the values for that indicator. The Grand Total Weight is the result of adding the weights of each indicator. Each indicator's weight is multiplied by the corresponding normalized value. Each multiplication's total weight is divided by the Grand Total Weight to develop the index. Hence, the formula that is used to ascertain the index is

$$I = \frac{\sum_{(i=1)}^{n} x_i[\sum_{(j=1)}^{n} L_{ij}\, Ej]}{\sum_{i=1}^{n}[\sum_{j=1}^{n} L_{ij}\, Ej]}$$

Where, I is the index, Xi is the i-th indicator's normalized value, Lij is the ith variable's factor loading value on the jth factor, and Ej is the jth factor's Eigen Value (NUEPA, 2009).

RESULTS AND DISCUSSION

Based on the PCA results, the eigenvalues, cumulative variance explained, and percentage of variance explained by the first five principal components obtained by PCA are shown in Table 1. Since they are components that significantly contribute to the explanation of total variance, the eigenvalues greater than 1 were kept. With an eigenvalue of 3.789, PC1 accounted for 18.04% of the variance. This suggested that a significant portion of the variability in the vendorship effectiveness indicators was captured by the first component alone. PC2 had an eigenvalue of 3.521 and explained 16.77% of the variance. The combined significance of financial and marketing considerations was highlighted by the fact that PC1 and PC2 together accounted for 34.81% of the variance. PC3 provided 16.37% of the variance and had an eigenvalue of 3.438. This means that the first three factors accounted for 51.18% of the variance, meaning that these three main factors might account for over half of the variation in vendorship effectiveness. The total variance explained increased to 63.08% when PC4 added an additional 11.90% variance (eigen value = 2.498). With an eigenvalue of 1.131, PC5 increased the total variance to 68.46% by explaining 5.38% of the variation. Overall, the first five components explained 68.46% of the variance, which is a respectably strong explanatory power in social science research, reflecting the robustness of PCA in analyzing complex dairy systems (Rathod *et al*. 2021; Kolekar *et al*. 2024).

While Fig. 1 illustrates that to assist in deciding how many components to keep in the analysis, the scree plot in the provided file shows the eigenvalues of the principal components presented in descending order. The plot's dramatic decrease in eigenvalues for the first few components suggested that they account for a sizable portion of the data's variation. The cutoff for significant components is shown by the 'elbow', or the point when the slope levels out. As per the findings, the first four main components, which together account for a sizable amount of the variance before the curve flattens out, are noteworthy. This implied that keeping these elements will simplify the data while succinctly summarizing the fundamental aspects of milk vendorship effectiveness. After this, other elements made very little contribution and might just be

Table 1. Principal components, Eigen values, percentage of variance explained by components, and accumulated percentage of variance explained by components

Principal components	Eigen values	% VPC	%VPC (accumulated)
PC1	3.789	18.043	18.043
PC2	3.521	16.766	34.809
PC3	3.438	16.373	51.183
PC4	2.498	11.895	63.078
PC5	1.131	5.383	68.461

PC, Principal components; Eigen values, variance; % VPC, percentage of variance explained by components

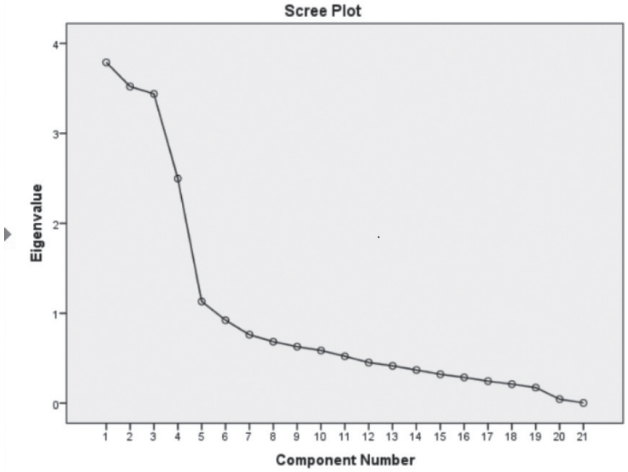

Fig 1. Scree Plot of Eigen values and component number

noise instead of significant patterns.

The PCA results, as depicted in Table 2, illustrated the underlying factors influencing the effectiveness of milk vendorship. The first five components explained a large proportion of the total variance, with the major share being accounted for PC1, PC2, and PC3.

The ability to analyze market competition (0.876), advertising (0.809), price in relation to the market (0.774), vendor innovation (0.735), broad product portfolio (0.692), and utilization of virtual platforms (0.678) were the main factors in PC1. This element demonstrated marketing and venture orientation by emphasizing the importance of competitive pricing, product variety, promotion tactics, analytical abilities, and innovation in boosting vendorship effectiveness. The prominence of competitiveness and financial performance as major components influencing milk vendorship effectiveness is in alignment with the findings of Sharma *et al*. (2022), who reported that pricing strategy, market orientation, and income-related variables were the primary determinants of effectiveness among informal dairy intermediaries. PC2 depicted very high loadings on gross income per day (0.989), average cost (0.924), average sale price (0.877), and milk sold per day (0.819). This dimension relates to financial performance, showing that better sales volume, optimal pricing, effective cost control, and profitability are essential for maintaining milk vendorship. PC3 loaded heavily on distance covered per day (0.865), time gap in delivery (0.861), customers served per day (0.859), time taken per client (0.851), and distribution logistics (0.717). This indicated customer access and distribution efficiency, where prompt delivery, customer base, accessibility to consumers, and reliable distribution networks substantially affect outcomes from vendorship. The emergence of operational efficiency as a distinct principal component corroborated with the observations of Kolekar and Venkatasubramanian (2023), who emphasized that logistics efficiency and customer accessibility significantly influence returns in traditional milk distribution systems. PC4 indicated significant loadings on utilization percentage (0.845), milk quality testing (0.806), ownership type (0.774), and use of milking machines (0.666). This dimension encompasses operational and institutional support, emphasizing how efficient use of resources, guarantee of product quality, institutional support, and adoption of milking technologies contribute to better performance. The contribution of infrastructure facilities and mechanization to vendorship effectiveness, though relatively moderate, aligns with the findings of (Nayak *et al*. 2020), who highlighted that ownership of resources, quality testing, and basic technological adoption enhance the performance of small-scale dairy enterprises. Despite the fact that PC5 explained relatively less variance, it emphasized the role of net returns per day (0.628) and risk handling during unforeseen circumstances (0.709), pointing to the importance of risk management and profitability as auxiliary elements of vendorship effectiveness.

Table 2. Factor loadings of corresponding principal components

Indicator	Principal Component (PC)				
	PC1	PC2	PC3	PC4	PC5
MSD	-0.074	0.819	0.027	-0.078	-0.117
ASP	0.138	0.877	-0.032	0.071	0.188
GID	0.012	0.989	0.021	0.028	0.083
AVC	0.075	0.924	-0.003	0.009	-0.187
NRD	-0.113	0.432	0.052	0.052	0.628
TG	-0.077	0.079	0.861	-0.006	0.109
CSD	-0.03	0.016	0.859	-0.004	-0.004
DCD	0.105	-0.013	0.865	-0.054	-0.023
TTC	0.039	0.007	0.851	0.055	0.111
DLG	0.046	-0.053	0.717	0.001	-0.078
OWN	0.048	-0.027	0.117	0.774	0.108
UTP	-0.145	0.089	-0.021	0.845	-0.173
MQT	0.057	-0.041	-0.034	0.806	0.006
MMN	-0.032	0.021	-0.091	0.666	0.358
AMC	0.876	-0.056	-0.011	-0.016	-0.018
PCM	0.774	0.153	-0.036	0.044	-0.046
DPP	0.692	0.02	0.064	-0.04	-0.135
INV	0.735	0.062	0.084	-0.032	-0.114
ADV	0.809	-0.124	0.101	0.043	0.025
VPL	0.678	0.039	-0.103	-0.037	0.109
RHUC	0.058	0.709	-0.057	-0.097	-0.219

MSD = Milk sold per day; ASP = Av. price of milk sold; GID = Income from milk per day; AVC = Cost incurred by vendors per day; NRD = Money earned by vendors; TG = Time difference in distributing milk; CSD= No. of customers served per day; DCD = Distance covered by vendors; TTC = Time taken by the vendor per client; DLG= Upto what extent the normal or cold chain used; OWN= Ownership status of resources; UTP= Quantity of milk sold and quantity held for own use; MQT = Frequency of milk testing per week; MMN= No. of vendors adopted machine milking; AMC = No. of vendors with idea of marketing analysis; PCM = Price difference of milk; DPP= Amount of milk used for products; INV = No. of milk products offered by vendors; ADV = No. of vendors engaged in brand building; VPL = No. of vendors using a virtual transaction platform; RHUC = No. of vendors with ability in handling milk.

Overall, the PCA results indicated that milk vendorship effectiveness is influenced by four key factors being financial performance, marketing and business orientation, customer and distribution efficiency, and operational/ institutional assistance. When combined, these elements offer a thorough framework for understanding and improving the sustainability of milk vendorship.

Weights of indicators and indices: As calculated using PCA, the constituent indicators of IGI, OEI, IFI, and CI carried distinct component weights. Among the 21 vendorship effectiveness indicators, there was a grand weight (W) of 57.834 (Table 3). The IGI contributed more than one-fourth (26.75 percent) to the EI's total weightage. Among the four indicators (X2), average sale price was

most important, as evident from the received highest weightage (3.890) followed by (X3) gross income/day (3.763), (X4) average cost (3.338), (X1) milk sold/day in liters (2.368), and (X5) net returns/day (2.111). The OEI contributed more than one-fifth (21.55 percent). (X9) Time taken/Client received the maximum weightage (3.361), followed by (X8) Distance covered/Day (3.165), (X6) Time gap (3.054), and (X7) Customer served/Day (2.881). The IFI contributed 17.65 percent. Among five indicators, (X11) Ownership received maximum importance (2.544), followed by (X10) Distribution logistics (2.367), (X13) Milk quality testing (1.974), (X14) Milking machine (1.708), and (X12) Utilization percentage (1.606). The CI contributed more than one-third (34.05) of the total weightage of EI. Among the seven indicators, (X16) price compared to market received maximum weightage (3.405), followed by (X19) advertising (3.111), (X18) innovativeness of the vendor (3.083), (X15) ability to analyze market competitiveness (3.023), (X17) diversified product portfolio (2.659), (X20) virtual platform (2.383), and (X21) risk handling during unforeseen circumstances (2.030).

Level of vendorship effectiveness: The cumulative cube root frequency method was employed to divide the sample of vendorship into three categories of effectiveness (Table 4). The vendors with an EI score ≤0.481 had a low level of effectiveness. Vendors with an EI score ranging from 0.481 to 0.607 had a medium level of effectiveness, and vendors ≥0.614 had a high level of effectiveness. From the score of EI, it was found that most of the vendors (36.70%) belonged to the category of low-level-of-effectiveness vendorship, while 32.50 percent of the vendors had a medium level of effectiveness, and only a smaller percentage of vendors (30.80%) were in the bracket of high-level-of-effectiveness vendorship. This variation among the respondents could be attributed to the level of initiative and managerial skills exhibited by vendors as they carried out each activity of dairy vendorship every day. A similar pattern of effectiveness distribution among dairy intermediaries has been reported in recent studies, where only a limited proportion of vendors operated at higher levels of efficiency due to superior managerial skills and adoption of innovation (Kumar *et al*. 2021).

A small number of vendors introduced innovations such as diversification in the production of milk products, the use of various machines for routine activities (milking, shed cleaning, milk quality testing, etc.), and digitalization, particularly in customer transactions and communication, which would somewhat reduce production costs and ultimately improve the effectiveness of existing ventures. In this venture, when family labor is extensively used, there are ample possibilities of reducing the production cost.

Table 3. Distribution of weights among the dimensions of EI and the respective indicators

Dimensions	Weight	Indicators	Weight
Income generation	15.473	(X_1) Milk sold/Day in Litres (+)	2.368
		(X_2) Average sale price (+)	3.890
		(X_3) Gross income/ Day (+)	3.763
		(X_4) Average cost (-)	3.338
		(X_5) Net returns/Day (+)	2.111
Operational Efficiency	12.462	(X_6) Time gap (-)	3.054
		(X_7)Customer served/Day (+)	2.881
		(X_8) Distance covered/Day (+)	3.165
		(X_9)Time taken/Client (-)	3.361
Infrastructure facilities	10.201	(X_{10}) Distribution logistic (+)	2.367
		(X_{11}) Ownership (+)	2.544
		(X_{12}) Utilization percentage (+)	1.606
		(X_{13}) Milk quality testing (+)	1.974
		(X_{14}) Milking machine (+)	1.708
Competitiveness	19.697	(X_{15})Ability to analyze market competitiveness (+)	3.023
		(X_{16}) Price compared to market (+)	3.405
		(X_{17}) Diversified product portfolio (+)	2.659
		(X_{18}) Innovativeness of the vendor (+)	3.083
		(X_{19}) Advertising (+)	3.111
		(X_{20})Virtual platform (+)	2.383
		(X_{21}) Risk handling during unforeseen circumstances (+)	2.030

(+) Positive indicator of effectiveness index (−) negative indicator of effectiveness index.

Table 4. Categorization of respondents' vendorship based on effectiveness index (n=120)

Effectiveness index score	Milk vendorship	
	f	%
Low (≤0.481)	44	36.70
Medium (0.481-0.607)	39	32.50
High (≥0.614)	37	30.80

F = Frequency, %= Percentage

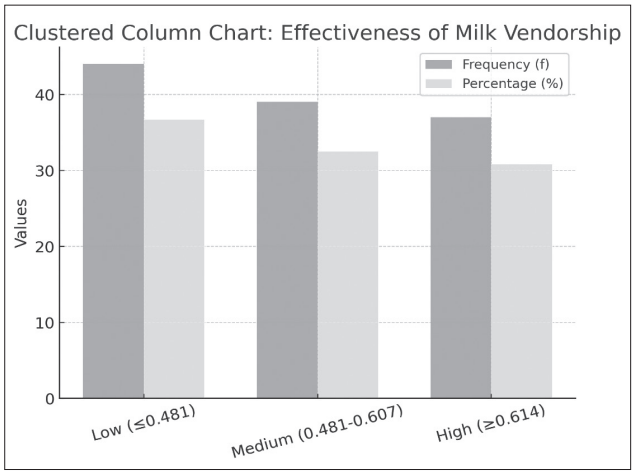

Fig 2. Categorization of respondents' vendorship based on effectiveness index

Mechanisation of certain operations such as distribution of milk, machine milking, and storage and processing of milk products would certainly reduce the production cost. Hence, it is crucial to understand the background of the vendorship and vendors so that effectiveness can be studied and corrective measures can be taken up to increase the work productivity. Need-based training can also be conducted to assist the vendors. Government can also support and encourage them by implementing exclusive programmes and schemes, as distribution of quality milk will ensure the health of milk consumers.

It may be concluded from the above study that vendors with medium and high-effectiveness level relatively more benefited from reduced cost, family labour and integration of technologies. Strengthening vendor capacities through government initiatives, need-based training, and mechanization assistance will optimize vendorship, ensuring the distribution of high-quality milk, increased income, and resistance to market fluctuations, ultimately leading to a sustainable dairy economy.

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