Original Research Article

Economic assessment of milk production with improved fodder in Tamil Nadu, Southern India: Two-stage least square approach

Abstract

Dairying has been an important auxiliary enterprise and regular source of income to the farmers. Indian dairy industry has grown commendably with the seven-fold rise in milk output since independence; however, the productivity of the milch animals was relatively low owing to inadequate fodder and inefficient input management. This study investigates the factors influencing milk production under enhanced fodder production in Tamil Nadu using the two-stage least square method. Primary data were obtained from 407 dairy farm households during the year 2021-22. Two models using single-cut and multi-cut fodder were employed to assess the factors determining milk production in dairy farms. The findings of the first stage regression of both models show that fertilizers, seeds, area under fodder, herd size, machinery, farming experience and education were the determinants of the fodder production. In the second stage, factors that influence milk production were fodder, concentrates, herd size, dairy experience, and education. Efficient utilization of feed coupled with concentrates will enhance milk production. The adoption of multi-cut fodder will offer succulent nutrient-rich fodder throughout the year to the cattle, even in the lean season and as a result, it improves the productivity of milk in the dairy farms.

Keywords: *Dairy, Milk Production, Multi-cut fodder, Two-stage least square, Tamil Nadu*

1. INTRODUCTION

Indian agriculture is primarily a crop-livestock production system with 70 per cent of the people involved in agriculture directly or indirectly [1]. Among different agricultural activities, farm households maintain milch animals as a supplement to their income and nutritional requirements. Given the monsoon's unpredictability and detrimental influence on crop output, dairy farming is considered an important source of income and employment that has made remarkable progress in recent years [2, 3]. India became the world's largest producer and consumer of dairy products by implementing Operation Flood in 1970 and subsequent dairy development programs. In 2018-19, the livestock industry accounted for 4.9 percent of total Gross Value Added (GVA). From 2014-15 to 2018-19, the contribution of livestock to total agriculture and allied sector GVA (at constant prices) has increased from 24.32 percent to 28.63 (Mohapatra et al., 2021). India emerged as the largest milk producer in 2019-20 with 198.4 million tonnes, comprising 96.64 million tonnes of cow milk, 96.23 million tonnes of buffalo milk, and 5.85 million tonnes of goat milk [4]. Meanwhile, Tamil Nadu is the tenth leading milk producing state (8.36 million tonnes) with 322 grams/day of per capita availability which is lesser than the country's per capita availability (394 grams/day) [5, 6]. Although India has a large livestock population, the production of milk and other livestock products, the productivity is relatively low compared to developed nations. The factors for the lower productivity were due to the under-utilization of resources and inputs. The important factor for the lower productivity of the milch animals was the deficit of fodder and feed in the lean periods. In India, fodder supplies can cover just 48 per cent of the demand, with a massive 61.1 per cent and 21.9 per cent deficits in green and dry fodder, respectively [7]. To make up for this shortfall, dairy farmers must increase their usage of expensive concentrate feeds, which eventually increases the cost of production. The only approach to bridge the gap between supply and demand for fodder is to optimise fodder production per unit area within existing agricultural systems. Multi-cut fodder sorghum is more favourable in various aspects, including increased yield in a short period, cost-saving on seed and land preparation [8]. As a result, it is quite popular among fodder crops with around five harvests per year, capable of producing high-quality feed in the mid to late-summer time frame [9]. The most popular multi-cut fodder sorghum cultivars in Tamil Nadu are CSV 33, CO(FS)29, and CO(FS)31 [8]. In order to increase milk production, the factors associated with it should be identified. This study focuses on determining the factors affecting the milk production on the dairy farms that uses sorghum single-cut and multi-cut fodder varieties.

2. DATA AND METHODOLOGY

The study was conducted in Tamil Nadu State using a random sampling method during the year 2021-22. At first, two districts viz., Namakkal and Salem were purposefully selected because of the heterogeneity of the dairy farms in Tamil Nadu, as most of the farms were in the rainfed zone [3]. Then, two blocks in each district and three villages in each block were selected randomly in the successive stages. Finally, a random sample of 407 dairy farm households was chosen and data on socio-demographic characteristics of the farmers and inputs used in dairy and fodder production were collected using a pretested questionnaire.

The study sought to assess the factors affecting the milk production of the dairy farms in Tamil Nadu. The milk production was estimated with the factors such as fodder, concentrates, herd size, the experience of the farmers in dairy and socio-demographic variables (age and education). The econometric model of the milk production is specified as;

$$\boldsymbol{M_i = f_i(FD_i,\ C_i,\ HS_i,\ DE_i,\ A_i,\ E_i)} \quad \textbf{(1)}$$

where, M_i is milk production (litres) of the dairy farm; FD_i is the fodder used in the dairy (tonnes); HS_i is the herd size of the dairy farm; DE_i is the experience of the farmer in dairy (years); A_i is the age of the farmer (years); E_i is the education or literacy level of the farmer (years). In the study area, farmers use two kinds of fodder for the cattle viz., single-cut and multi-cut fodder varieties. The milk production was estimated in farms that use single-cut fodder sorghum (i=1) and multi-cut fodder sorghum since they have different production technologies.

In dairy farms, milk and fodder production are inextricably connected, as the land is primarily utilised to provide feed for ruminants. If farmers choose their fodder production endogenously, it will correlate with the error component in equation (1), rendering the parameter estimates inconsistent and inefficient. Consistent and efficient estimates under this endogeneity condition might be produced by estimating the milk production equation in its reduced form and including explanatory factors [10]. The equation of the fodder production was introduced to nullify the endogeneity problem and it is specified as;

$$\boldsymbol{FD_i = f_i(FT_i, S_i, MN_i, AF_i, ME_i, L_i,\ HS_i, FE_i, A_i, E_i)} \quad \textbf{(2)}$$

where, FT_i is the fertilizers used (kilograms), S_i is the seeds (kilograms), MN_i is the manure (kilograms), AF_i is the area under fodder production (hectares), L_i is the labour used (man days), ME_i is the machineries used (hours); HS_i is the herd size of the dairy farm; FE_i is the farming experience of the farmer (years); A_i is the age of the farmer (years) and E_i is the education or literacy level of the farmer (years).

The econometric model includes equations (1) and (2) and they are estimated by Two-Stage Least Squares (2SLS), because the fodder production (FD_i) might be endogenous which correlates with the error term and they result in inconsistent estimates of the milk production. The 2SLS estimation is the standard approach to solve the endogeneity problem and generate unbiased estimates [11]. The two-stage least square estimation is done at two stages. In the first stage, the estimated value $\widehat{FD}_i$ for fodder is estimated in equation 2. In the second stage, observations for endogenous fodder FD_i were replaced by the estimated values. Then the equation for the milk production (equation 1) was estimated.

A couple of tests were conducted to determine the most appropriate simultaneous equation model, as estimation with simultaneous equations is frequently subject to endogeneity and simultaneity problems. Multiple correlation test and the Durbin–Wu–Hausman test of endogeneity were used to determine relevancy (a high correlation between the instrument variable and endogenous regressors that other instruments cannot explain) and exogeneity (no correlation with the dependent variable's innovations) [12]. Durbin–Wu–Hausman test was used to test the endogeneity of the fodder equation. Under the null hypothesis, fodder was considered as an exogenous variable in equation (1), and it does not correlate with the error term. Even if the null hypothesis holds, 2SLS results in consistent estimates but they are inefficient [13].

3. RESULTS AND DISCUSSION

The descriptive statistics of the selected variables for the two-stage least square were furnished in Table 1. According to the results, the respondents were middle-aged (48 years) and small farmers (3.81 ha) with a secondary level of education. The majority of farm households have a herd of 3 cattle animals. The mean milk production in the dairy farms was 19059.06 (model 1) and 22895.21 litres per year (model 2) by using single-cut sorghum fodder 18932.56 kg in model 1 and multi-cut sorghum fodder 22895.21 kg in model 2.

3.1. Reliability ~~test~~ Test of the ~~model~~Model

A relevancy test (multiple correlation) was used to establish the relationship between the instrument variables and the endogenous variable (Table 2) [12]. In model 1 (single cut), the endogenous variable fodder was positively correlated with fertiliser (0.81), area under fodder (0.81), labour (0.79), seed (0.67), and labour (0.66). (0.70). In case of model 2, fodder production was highly correlated with fertilizer (0.96), seed (0.92), area under sorghum (0.91), machineries (0.76), labour (0.62) and manures (0.61). These higher correlation coefficient values show that the instrumental variables in the model are more relevant to their endogenous variables. These greater correlations suggest that all of the instrument variables included in the models satisfy the relevancy test for the corresponding endogenous variable i,e., fodder. The Durbin-Wu-Hausman test was employed to test the potential endogeneity issue associated with the fodder variable [14, 15, 16]. The values of Durbin Chi-Square and Wu-F Hausman's statistics for single cut (2.45 and 2.75) and multi-cut (2.01 and 3.17) models were insignificant, as shown in Table 3. This demonstrates that the right-hand side of the milk production equation had no endogenous variables. Weak instruments may result in biased instrumental variable (IV) estimators and hypothesis tests with large size distortions [17]. As a result, the F test was used to identify the weak instruments in the model. The findings of Table 4 reveal that the robust F-statistics for fodder production were found to be significant, indicating that the instrument variables, namely fertilisers, seeds, manures, area under fodder production, machinery, and labour were very strong. The relevancy results, Durbin–Wu–Hausman and weak instrument tests emphasized that the model in this study is appropriate for the simultaneous equation analysis.

Table 1. Descriptive ~~statistics~~ Statistics of the ~~determinants~~ Determinants ~~selected~~ Selected for 2SLS ~~model~~Model

Variables	Model 1 (Single cut)				Model 2 (Multi-cut)			
	Mean	Min.	Max.	Std. dev.	Mean	Min.	Max.	Std. dev.
Milk (Litres/year)	19059.06	2415.00	91500.00	26410.86	22895.21	2645.00	94975.00	27783.86
Fodder (Kilograms)	18932.56	2034.33	205826.67	24373.82	24735.29	2273.67	936607.07	70318.12
Concentrates (Kilograms)	7956.06	690.00	107640.00	11740.67	7909.97	712.00	156802.50	14159.21
Herd size	2.77	1.00	30.00	8.78	3.58	3.00	34.00	12.97
Fertilizers (Kilograms)	86.18	0.00	2000.00	212.54	113.02	0.00	7525.00	560.69
Manures (Tonnes)	2.28	0.00	45.00	5.16	3.22	0.00	150.00	11.37
Seed (Kilograms)	17.79	8.00	105.00	17.31	18.04	12.00	150.00	17.96
Area under fodder (Hectares)	0.70	0.08	6.07	0.73	0.87	0.27	12.15	1.00
Machineries (Hours)	7.12	2.75	32.00	15.78	8.49	1.00	48.00	8.19
Labour (Man days)	68.75	30.00	129.00	35.72	94.51	48.00	210.00	28.25
Age (Years)	48.51	27.00	70.00	12.45	48.02	30.00	75.00	12.44
Education	10.17	0.00	16.00	2.19	11.87	4.00	15.00	2.54
Farming Experience	19.54	1.00	50.00	8.54	17.28	2.00	50.00	9.09
Dairy Experience	10.99	3.00	20.00	4.96	11.54	3.00	20.00	5.15

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Table 3. Durbin–Wu–Hausman ~~test~~ Test of ~~endogeneity~~Endogeneity

Equation	Durbin Chi-Square score		Wu-Hausman F stat		Null Hypothesis	Decision
	Single cut	Multi-cut	Single cut	Multi-cut		
Milk = *f* (fodder, concentrates, herd size, dairy experience, age, education)	2.45 (p=0.192)	2.01 (p=0.21)	2.75 (p=0.49)	3.17 (p=0.12)	Variables are exogeneous	Failed to reject null hypothesis

Table 4. Weak ~~instruments~~ Instruments ~~test~~Test

Equation	Robust F-statistics		Null Hypothesis	Decision
	Single cut	Multi-cut		
Fodder =*f* (fertilizer, seeds, manure, area, machineries, labour, farming experience)	4.26 (p=0.00)	8.08 (p=0.00)	Instruments are weak	Reject the null hypothesis

3.2. Estimated ~~elasticities~~ Elasticities of ~~two~~Two-~~stage~~ Stage ~~least~~ Least ~~square~~Square

The diagrammatic representation of inter-relationships between the variables is given in Figure 1. The estimates of first-stage ordinary least square results are presented in Table 5. The first-stage estimation included seven instrumental variables, fertilizers, seeds, manure, the area under fodder, machinery, farming experience, and labor, that were not part of the second-stage estimation for identification [18]. In model 1, the single-cut sorghum fodder production was positively influenced by the factors such as fertilizers, seeds, area, herd size, machinery, farming experience, age and education. The inputs such as the fertilizers and seeds are inevitable to the agricultural production systems and were positively significant. The results imply that one percent increase in fertilizers and seeds would increase the sorghum fodder production by 0.21 and 0.25 per cent, respectively. Area under cultivation is also an important factor that directly affects the production scale. The area under sorghum production appeared to be positively significant at 5 per cent level and its one per cent increase would enhance the fodder production by 1.02 per cent. Since change in area is highly responsive to fodder production, any variation in area due to climatic conditions, price fluctuations, or government policies may have a detrimental effect on production and its stability [19]. Herd size was positively significant at 1 per cent at level and one per cent

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increase in herd size would increase the fodder production by 0.45 per cent. Similarly, machineries, farming experience and education have positively influenced the fodder production. For instance, one per cent increase in machinery, farming experience and education would increase fodder production by 0.04, 0.13 and 0.15 per cent, respectively. Several studies have found that education is an important factor that significantly influences the adoption of new generation inputs, new advanced technologies, etc. These studies recognize that farmer's capacity is found to be effective and productive if they were educated. Farmer's education and skills play a significant role in explaining the performance of the farmers in the production, alongside the availability and potential of natural resources such as land and water, as well as infrastructure and institutional investments in inputs, credit, and research [20, 21].

In the second stage of ~~model~~ Model 1, the estimates of the fodder obtained from the first stage was used as an explanatory variable. From table 6, all the variables except the age of the farmers have a positive relationship with milk production. The results indicate that a one per cent increase in fodder, concentrates, herd size, dairy experience, age, and education would increase the milk production by 0.18, 0.31, 6.12, 0.13 and 0.30. It reveals that the milk production in the dairy farms of the study area would increase whenever there is an increase in usage of fodder and concentrates and it would be applicable even if the herd size is increased.

In the case of ~~model~~ Model 2, the explanatory variables in the first stage like fertilizers, seeds, area under sorghum, herd size and education were positively significant at one per cent. Similarly, manure, machinery and farming experience were significant at five per cent level and labour was positively significant at 10 per cent. The results indicated that one per cent increase in fertilizers, seeds, manure, area under sorghum, herd size, machinery, labour, farming experience and education would increase milk production by 0.40, 0.30, 0.08, 1.58, 0.62, 0.22, 0.19, 0.01 and 0.19 respectively. Whereas in the second stage, all the explanatory variables except age were positively influencing the milk production.

Figure 1. Milk ~~production~~ Production ~~model~~Model

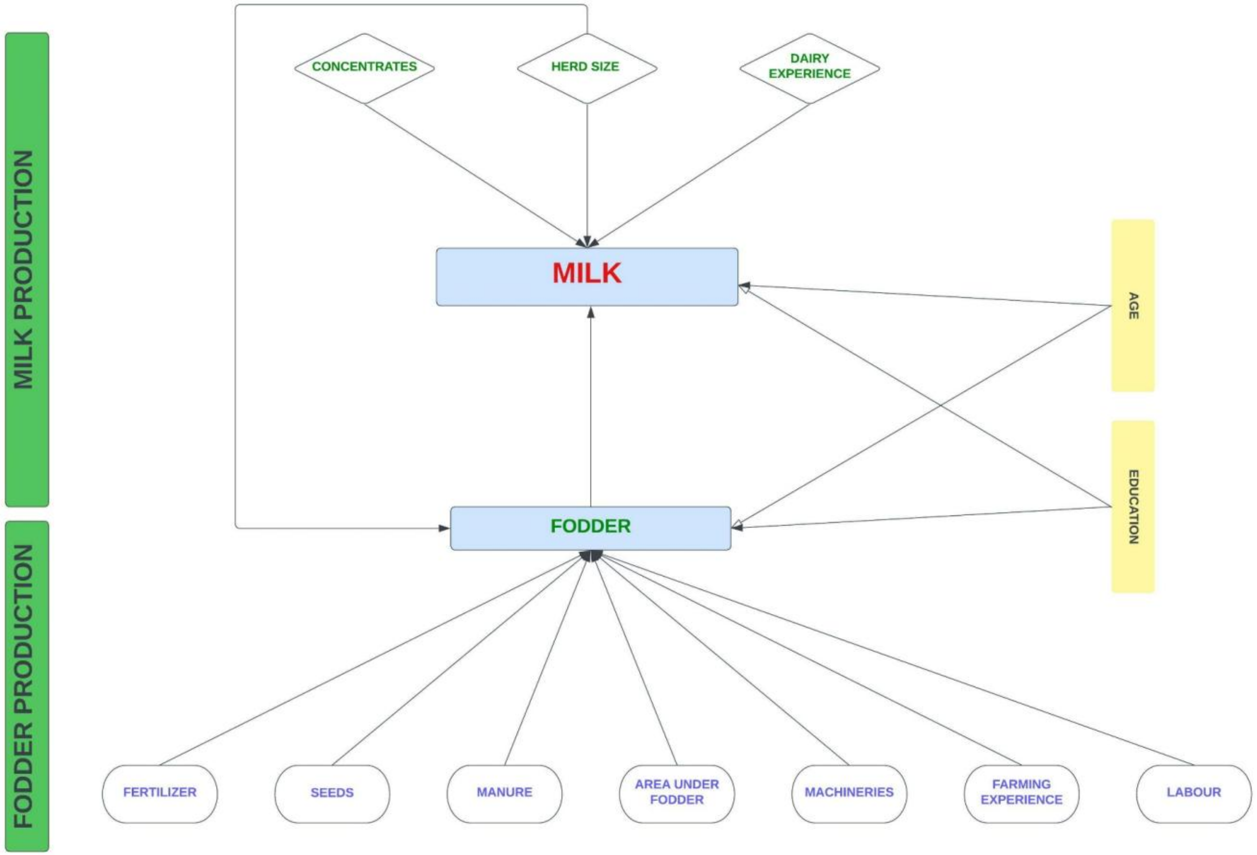

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Table 5. Estimated coefficients of fodder production at the first stage of 2SLS

Variables	Model 1 (Single Cut)			Model 2 (Multi-cut)		
	Coefficient	Std. Error	P-value	Coefficient	Std. Error	P-value
Fertilizers	0.21***	0.05	0.00	0.40***	0.16	0.00
Seeds	0.25**	0.10	0.04	0.30***	0.16	0.00
Manure	0.01	0.00	0.12	0.08**	0.05	0.05
Area under sorghum	1.02**	0.32	0.01	1.58***	0.43	0.00
Herd size	0.45***	0.14	0.00	0.62***	0.18	0.00
Machinery	0.04*	0.08	0.07	0.22**	0.29	0.02
Labour	0.01	0.00	0.24	0.19*	0.21	0.08
Farming Experience	0.13**	0.20	0.04	0.01**	0.00	0.02
Age	0.42	0.26	0.11	1.24	0.05	0.18
Education	0.15***	0.05	0.00	0.19***	0.04	0.00
Constant	118.56***	23.14	0.00	141.22***	28.92	0.00
R-square	0.79			0.88		
Observations	251			156		

Table 6. Estimated coefficients of milk production at the second stage of 2SLS

Variables	Model 1 (Single Cut)			Model 2 (Multi-cut)		
	Coefficient	Std. Err	P-value	Coefficient	Std. Error	P-value
Fodder	0.18**	0.09	0.03	0.26***	0.07	0.00
Concentrate	0.31***	0.11	0.00	0.42***	0.09	0.00
Herd size	6.12**	4.18	0.02	7.32***	0.02	0.00
Dairy Experience	0.13*	0.37	0.05	0.62**	0.24	0.03
Age	0.23	0.13	0.07	0.14	0.11	0.18
Education	0.30**	0.10	0.01	0.25**	0.12	0.04
Constant	1.29***	0.09	0.00	1.43***	0.12	0.00
R-square	0.84			0.90		
Observations	251			156		

******* Significant at 1 per cent level, ** Significant at 5 per cent level and * Significant at 10 per cent level

From the results, it is evident that the fodder, concentrates and herd size were the major influencers of the milk production. The estimated coefficient of fodder in ~~model~~ Model 1 was higher than the corresponding coefficient in ~~model~~ Model 2. It implies that the multi-cut sorghum fodder has more effect on milk production than the single-cut fodder varieties. This enhanced milk produced might be attributed due to the higher nutritional quality of the multi-cut fodder. However, the stover obtained from single-cut sorghum varieties is typically fed to the cattle after harvest. Due to the high crude fibre content and low crude protein content of this straw, it does not make good fodder for milch cattle. There has long been a desire for multi-cut fodder sorghum with approximately five cuts per year to reduce seed costs and improve conditions for supplying green forage to dairy farms [22]. Multi-cut fodder sorghum is more advantageous in various ways, including high yield in a short time and cost-saving in seed and land preparation. As a result, it is extremely popular among fodders. Cuts range between 5 and 6 per year, giving succulent nutrient-rich fodder throughout the year to the cattle even in the lean season and its yield response due to the fertilizer is higher in the case of multi-cut sorghum varieties [23]. The multi-cut sorghum fodder would provide a regular supply of fodder to the dairy farms throughout the year, thereby increasing milk production.

4. CONCLUSION

As a result of structural changes in the Indian dairy sector, especially in input management, the present study explores the determinants of milk production based on a farm household survey. Fertilizers, seeds, area under fodder, herd size, machinery, farming experience, and education were the key determinants of fodder output in the first stage of a two-stage least squares analysis method. There is evidence that factors such as fodder, concentrates, herd size, dairy experience and education were the determinants of the milk production in the second stage. The milk productivity of the dairy farms might be improved by producing multi-cut sorghum fodder varieties that ensure nutritious fodder all year round and by using concentrates optimally. There should be an effort made to spread knowledge about the advantages of multi-cut fodder and increase the area under multi-cut varieties by implementing fodder development programs.

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