Economic performance of exotic dairy cattle under smallholder conditions in the marginal zones of Kenya using three analytical approaches

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Abstract

Smallholder exotic dairy cattle have been adopted in the dry marginal zones of Kenya from the high potential areas over the last two decades contrary to the opinion of experts. The objective of this study therefore was to evaluate the economic performance of this dairy establishment in the marginal zones. Three approaches were used for the evaluation: the stochastic cost frontier to determine inefficiencies and the causative institutional and socio-economic factors; cost-factor demand systems; and the supply response analyses to determine the elasticity estimates of policy variables. The results from these approaches are supplementary and seem to support the need for government interventions in institutional and socio-economic factors that have a high public good component in order to expand dairy establishment in the marginal zones.

Keywords: Marginal zones; stochastic frontier; systems analysis; institutional and socio-economic factors

1. Introduction

The economic performance of smallholder exotic dairy cattle in the marginal zones of Kenya is the theme of this study. This evaluation is analysed from three different but interrelated perspectives. Smallholder exotic dairy cattle have been adopted in the marginal zones from the high potential areas of Kenya over the last two decades, contrary to the opinion of experts (Kimenyi & Russell, 1975). It is a new, alternative enterprise that offers higher returns, has the potential for future growth, and is suitable for poor smallholder farmers who dominate agricultural production in the marginal zones (Nicholson *et al*., 2004). The challenge for the transition to the next stage is to intensify dairy production and achieve the greatest possible output given the available resources and the new dairy technologies.

Agriculture provides employment to the majority of the people in the marginal districts (Republic of Kenya, 2002). However, rainfall reliability is low and

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frequently results in drought and crop failure, worsening the food security situation in the region (Mbithi & Huylenbroeck, 1999). There are no established cash crops in the marginal zones. Neither are there off-farm employment activities, such as tourism and the fisheries industry, as in the coastal parts of Kenya. Household incomes in the marginal zones are low and over 60% of the population lives below the poverty line (Republic of Kenya, 2000). Ultimately, reduction of poverty remains one of the greatest challenges. Therefore, the importance of the dairy industry in the marginal lands of Kenya cannot be overemphasised. Market-oriented dairy production seems to have partially filled the needs for smallholder producers in the marginal zones. However, the performance of this newly established milk enterprise faces a great challenge. This is because the marginal zone environment is relatively hot, dry and potentially hostile to exotic breeds, which are only familiar with temperate climates. Further, smallholder farmers in the marginal zones have experienced profound technical, economic and an increasingly changing policy environment in the recent past. In such a dynamic system, farmers find it difficult to adjust allocation decisions to keep pace with changes in their environment and, at the same time, to maintain the production structure and supply response performance expected of the exotic dairy breeds. The research problem statement is the continued establishment of high exotic grade dairy in the marginal zones, in spite of their potentially low economic performance in such relatively hostile dry areas and a volatile agricultural policy environment in the last two decades.

2. Analytical approaches to dairy performance in the marginal zones

The goals of the study were to identify the socio-economic and institutional factors that influence the efficiency of dairy practices, to determine the production structure and to determine the supply response of dairy farmers in the marginal zones. To achieve these objectives, three interrelated approaches to production analysis were employed. The first approach uses the stochastic frontier framework to determine socio-economic attributes and institutional factors that influence cost inefficiencies and estimates their impacts. In the second and the third approaches, dairy production structure and supply response are analysed using the systems approach framework, which permits the measurement of different impacts that exogenous variables have within and across dairy input demands and milk supply. Information derived from this study might help decision makers allocate resources on the basis of the greatest possible response from the producers. Our contribution is to demonstrate that milk supply, costs and input demands are an integrated, simultaneous system of activities in dairy production and that the non-price factors of social and institutional factors evoke a far greater response from dairy farmers than the price factors, even in a liberalised market environment. The purpose of the study was to determine the economic performance of dairy establishments in the marginal zones. The analytical approaches used are discussed briefly below.

2.1 Stochastic frontier cost function

The stochastic frontier cost function was used in this study to estimate cost inefficiencies of exotic dairy breeds. The institutional and socio-economic factors responsible for these inefficiencies were also established. The study adopted a stochastic frontier based on the Battese and Coelli (1995) model. The cost function approach is preferred over the profit function approach to avoid problems of estimation that may arise in situations where households realise zero or negative profits. The stochastic cost function is defined as:

$$C_i = f(y_i, w_i) + (v_i + u_i) \tag{1}$$

where v_is values are assumed to be independently and identically distributed $N(0,\sigma^2_v)$ two-sided random errors, independent of the u_is. The u_is are non-negative unobservable random variables associated with cost inefficiency, and are assumed to be identically and independently distributed as truncations at zero of the \N(0 , σ^2_u)\ distribution. In the cost inefficiency effects model, the error term is composed of cost inefficiency effects and statistical noise. The inefficiency model could be specified as:

$$u_i = \delta z_i + W_i \tag{2}$$

where z_i is a vector representing possible efficiency determinants, and δ is a vector of parameters to be estimated. W_i, the random variable, is defined by the truncation of the normal distribution with mean zero and variance σ^2. The parameters of the stochastic frontier and the inefficiency model are estimated simultaneously. u_i provides information on the level of cost inefficiency of farm i. The level of cost inefficiency CI_i may be calculated as the ratio of frontier minimum cost to observed cost. An estimated measure of cost efficiency for dairy farm i is:

$$CI_i = \exp(-u_i) \tag{3}$$

The translog cost function is chosen due to its flexibility and its variability in elasticity (Sadoulet & De Janvry, 1995). The stochastic frontier translog cost function is defined as:

$$\ln C_i = \alpha + \alpha_q \ln Q_i + \sum_i^n \alpha_i \ln P_i + \frac{1}{2}\beta_{qq}(\ln Q_i)^2 + \frac{1}{2}\sum_i^n \beta_i \ln P_i \ln P_i + \sum_i^n \beta_{ij} \ln P_i \ln P_j$$
$$+ \sum_{i=1}^n \beta_{qi} \ln Q_i \ln P_i + \gamma_m \ln Z_m + \frac{1}{2}\gamma_{mm}(\ln Z_m)^2 + \sum_{m,i}^n \gamma_{mi} \ln Z_m \ln P_i + \sum_{m,q}^n \gamma_{mq} \ln Z_m \ln Q_i + e_i \tag{4}$$

The symmetry assumption holds, i.e. $c_{ij} = c_{ji}$ and $h_{mi} = h_{im}$.

The inefficiency model (u_i) is defined as:

$$u_i = \delta_0 + \sum_{d=1}^{n} \delta_d W_d + \omega \quad (5)$$

where C_i represents total production cost, Q_i represents annual output of milk (litres), P_i is a vector of variable input prices, Z_m is the vector of fixed inputs and e_i is the disturbance term. W_d is a vector of variables explaining inefficiency in the model.

Following Aigner *et al.* (1977), the disturbance term (e_i) is assumed to be a two-sided term representing the random effects in any empirical system. The stochastic frontier cost models, equation 4, with the behavioural inefficiency model, equation 5, were estimated in one-step Maximum Likelihood Estimation using LIMDEP (Greene, 2002).

2.2 Translog cost function systems analysis

The second area of analysis in this study determines the production structure of dairy in the marginal zones. An industry's production structure can be studied empirically using either a production function or a cost function. However, the choice should be made on statistical grounds (Kant & Nautiyal, 1997). Direct estimation of the production function is more convincing in the case of endogenously determined output levels, while in the case of exogenously determined output levels the cost function estimation is preferable (Christensen & Green, 1976).

In most cases, the dairy sector competes with other enterprises for factors of production, and this leads factor prices to be exogenous. Since the arguments of the cost function are the output and the factor prices, its estimation is statistically more logical than that of the production function. On the other hand, duality theory allows for the recovery of all information regarding the production structure from the cost function. Because of very specific features, i.e. no *a priori* restrictions on the substitution possibilities and variation of scale economies with the level of output (which is essential to enable the unit cost curve to attain the classical U-shape), the translog cost function (Christensen *et al.*, 1971, 1973) has been chosen for this analysis.

A general form of the translog cost function for seven inputs (protein feeds, roughage feeds, animal treatment, tick administration, labour, own produced feeds and grazing area) can be expressed as:

$$\ln C_i = \alpha + \alpha_q \ln Q_i + \sum_i^n \alpha_i \ln P_i + \frac{1}{2}\beta_{qq}(\ln Q_i)^2 + \frac{1}{2}\sum_i^n \beta_{ii} \ln P_i \ln P_i + \sum_i^n \beta_{ij} \ln P_i \ln P_j$$
$$+ \sum_{i=1}^n \beta_{qi} \ln Q_i \ln P_i + \gamma_m \ln Z_m + \frac{1}{2}\gamma_{mm}(\ln Z_m)^2 + \sum_{m,i}^n \gamma_{mi} \ln Z_m \ln P_i + \sum_{m,q}^n \gamma_{mq} \ln Z_m \ln Q_i \quad (6)$$

where $\beta_{ij} = \beta_{ji}$ for all i, j, and the function is homogeneous of degree one in prices of all variable inputs and output. The definition of the variables and the notation used are as follows:

C_i = Total variable cost of production normalised by the labour wage (w_i);
P'_i = Price of the ith input (P_i) normalised by the labour wage (w_i);
i = 1: protein feeds; 2: roughage feeds; 3: animal treatment; 4: tick administration; 5: own produced feeds;
Z_m = grazing area;
$\alpha's, \beta's$ and $\gamma's$ are the parameters to be estimated.

To correspond to a well-behaved production function, a cost function must be homogeneous of degree one in the input prices, which requires the following conditions to be satisfied:

$$\sum_i \alpha_i = 1 \quad (7)$$
$$\sum_i \beta_{qi} = 0 \quad (8)$$
$$\sum_i \beta_{ij} = \sum_j \beta_{ij} = \sum_i \sum_j \beta_{ij} = 0 \quad (9)$$

The restriction of linear homogeneity in the input prices is imposed by normalising cost and the other prices by the labour wage rate (Green, 2002). The translog cost function can be estimated directly or in its first derivatives which, by Shepard's Lemma gives the factor shares. Thus, logarithmically differentiating equation 6 with respect to input prices yields:

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{P_i X_i}{C_i} = S_i \quad (10)$$

where S_i indicates the cost share of the ith input factor. The translog cost function thus yields the cost share equations:

$$S_i = \alpha_i + \beta_{qi} \ln Q + \sum_i \beta_{ij} \ln P_j + \gamma_{ij} \ln Z_m \quad (11)$$

and i = 1 for protein feed share, 2 for roughage feed share, 3 for tick control share, 4 for treatment administration share, 5 for labour input share and 6 for own produced feed share. Both sets of estimation equations are linear in logarithms and have proper exogenous variables on the right-hand side if the analysis pertains to firm-farms or an industry (Binswanger, 1974). The necessary cross equation constraints are imposed in the translog cost function and the input demand system. Within the factor demands, symmetry of the input demand equations (i.e. $\beta_{ij} = \beta_{ji}$) is imposed. It is generally observed that very large gains in efficiency often follow when the cross equation restrictions are imposed (Green, 2002). The optimal procedure was to jointly estimate the cost function simultaneously with the cost share equations as a multivariate regression system. Additive disturbances were assumed for the cost function as well as for each of the share equations. Following Zellner (1962), it was also assumed that the error in each equation was homoscedastic, but that there was a nonzero correlation between contemporaneous disturbance terms across equations. In view of the adding up requirement of the input shares, one equation, labour input demand share, was excluded from the system. By deleting one of the share equations from the system and using the iterative Zellner estimation procedure until convergence, maximum-likelihood estimates were realised. The β_{ij} parameters estimated have little economic meaning of their own. However, they are related to the variable elasticities of substitution, factor demands (Binswanger, 1974) and economies of scale, which were computed after the estimation of these coefficients.

2.3 Translog profit function systems analysis

Supply response analysis takes into account the impacts of the price factors on output supply and profit, which are of much interest in policy decisions. In addition, it accounts for impacts of institutional and socio-economic setups on production structure, which is of much concern to policy makers. Therefore, this method explores the response of dairy farmers to changes not only of price factors, but also of institutional and socio-economic setups related to technology and fixed inputs, using profit function approach.

Specifically, the dairy households would be assumed to maximise 'restricted' profits, defined as the gross value of output less variable costs, subject to a given technology and given quantities of fixed factors. The resultant profit function depicts the maximum profit attainable for given input and output prices, the availability of fixed factors and the production technology. As we are dealing with a single output, liquid milk production, it is convenient to specify a normalised profit function, and fixed factors.

The profit function has two interesting properties: its derivative with respect to the price of a product is equal to the supply function of that product; and its derivative with respect to the price of an input is equal to the negative of the demand function of that input (Sadoulet & De Janvry, 1995). These relations, called the Shephard's duality Lemma, are derived by differentiating the profit function and taking advantage of the first order conditions of the maximisation problem. By solving the maximisation problem, the behavioural equations of output supply and factor demands are obtained. It is desirable to estimate the input demand and output supply equations simultaneously. Such estimation is facilitated by the profit function approach which permits joint estimation of the profit and factor demand equations and ensures consistent parameter estimates (Sidhu & Baanante, 1981; Subramaniyan & Nirmla, 1991; Farooq *et al.*, 2001). This framework was adopted for this study.

A generalisation of the normalised restricted translog profit function for a single output, e.g. liquid milk production, is given by Farooq *et al.* (2001) and Sidhu and Baanante (1981):

$$\ln \pi^{'} = \alpha_0 + \sum_{j=1}^{5} \alpha_i \ln P^{'}_i + \frac{1}{2}\sum_{j=1}^{5}\sum_{k=1}^{5} \gamma_{ij} \ln P^{'}_i \ln P^{'}_j + \sum_{j=1}^{5}\sum_{l=1}^{6} \delta_{ik} lnP^{'}_i \ln Z_k + \sum_{l=1}^{6} \beta_k \ln Z_k + \frac{1}{2}\sum_{l=1}^{6}\sum_{t=1}^{6} \theta_{lt} \ln Z_k \ln Z_h + \varepsilon \quad (12)$$

where $\gamma_{ij} = \gamma_{ji}$ for all i, j and the function is homogeneous of degree one in prices of all variable inputs and output. The definition of the variables and the notation used are as follows:

$\pi^{'}$ = Restricted profit normalised by the price of output (P_y);
$P^{'}_i$ = Price of the jth input (P_i) normalised by the output price (P_y);
i = 1: protein feeds; 2: roughage feeds; 3: animal treatment; 4: tick administration; 5: wage rate
Z_k = quantity of fixed input k :-
k = 1: grazing area; 2: years of education; 3: extension visits; 4: walking ratio to tarmac road; 5: number of cows; and 6: distance to water point
$\alpha_0, \alpha_i, \gamma_{ij}, \delta_{ik}, \beta_k, \theta_{kh}$ are parameters to be estimated.

Define $S_j = P_j X_j / \pi'$ as the ratio of variable expenditures for the ith input relative to restricted profit**.** Let $S_y = Y / \pi'$ be the ratio of output supply (Y) to normalised, restricted profit. S_y is also equivalent to the ratio of the total value of output to restricted profit. Differentiating the translog profit function (12) with respect to $\ln P_i$ and $\ln P_y$ gives a system of variable input/profit ratio functions and an output supply/ profit ratio functions (Christensen *et al.*, 1973), as shown in equations 13 and 14 respectively:

$$S_i = \frac{P_i X_i}{\pi'} = -\frac{\delta \ln \pi'}{\delta \ln P_i} = -\alpha_i - \sum_{k=1}^{5} \gamma_{ij} \ln P'_j - \sum_{l=1}^{6} \delta_{il} \ln Z_k \quad (13)$$

$$S_y = \frac{P_y Y}{\pi'} = 1 + \frac{\delta \ln \pi'}{\delta \ln P_y} = 1 - \sum_{j=1}^{5} \alpha_i - \sum_{i=1}^{5}\sum_{k=1}^{5} \gamma_{ij} \ln P'_j - \sum_{l=1}^{6} \delta_{ik} \ln Z_k \quad (14)$$

where S_i is the share of ith input, S_y is the share of output, X_i denotes the quantity of input i and Y is the level of liquid milk output. Since the input and output shares form a singular system of equations (by definition $S_y - \sum S_i = 1$), one of the share equations, the output share, is dropped and the profit and factor demand equations for protein feeds, roughage feeds, animal treatment, tick administration, and labour are estimated as a simultaneous system. Under the liberalised environment of the dairy farms, the normalised input prices and quantities of fixed factors are considered to be the exogenous variables. In terms of the regularity properties of the profit function, homogeneity was imposed automatically because the normalised specification was used. The convexity property was assumed to hold and was not tested. However, the symmetry restriction was tested formally in this study.

The parameter estimates of equations 12 and 13 were used to estimate the elasticities related to variable input demands, output supply and the profit function. These elasticity estimates represent the structure of supply response for the dairy farms in the marginal areas. They are policy variables that indicate different impacts that exogenous variables have within and across input demand and output supply functions. They are evaluated at averages of the S_i and, at given levels of variable input prices (for the case of variable factors), are linear transformations of the parameter estimates of the profit function. These elasticities were obtained using the following formulae (see Sidhu & Baanante, 1981; Farooq *et al.*, 2001):

The own-price elasticity of demand for variable input i (η_{ii}) was estimated as:

$$\eta_{ii} = -S_i - \frac{\gamma_{ii}}{S_i} - 1 \tag{15}$$

where S_i is the ith share equation, at the sample mean. For the cross-price elasticity of demand for ith variable input with respect to the price of jth variable input (η_{ij}), the following expression will be used with respect to output price:

$$\eta_{ij} = -S_j - \frac{\gamma_{ij}}{S_i} \text{ for } i \neq j \tag{16}$$

The following equation will be used for estimating the elasticity of demand for variable input with respect to output price, P_y, (η_{iy}):

$$\eta_{iy} = S_y + \sum_{j=1}^{5} \frac{\gamma_{ij}}{S_i} \tag{17}$$

where S_y is the output share, at the sample mean. Finally, the elasticity of demand for variable input with respect to *kth* fixed factor, (η_{ik}), will be determined as:

$$\eta_{il} = \left(\beta_k + \delta_{ik} \ln P_i + \sum \theta_{kh} \ln Z_h \right) - \frac{\delta_{ik}}{S_i} \tag{18}$$

The own-price elasticity of supply, η_{yy}, is determined as:

$$\eta_{yy} = \sum_{i=1}^{5} S_i + \frac{\sum_{j=1}^{5} \gamma_{ij}}{S_y} \tag{19}$$

whereas the elasticity of output supply with respect to price of ith variable output η_{yi} is given by:

$$\eta_{yi} = -S_i - \frac{\sum_{j=1}^{5} \gamma_{ji}}{S_y} \tag{20}$$

The elasticity of output supply with respect to fixed input $k, (\eta_{yk})$ is computed as:

$$\eta_{yk} = \left(\beta_k + \sum_{i=1}^{5} \delta_{ik} \ln P'_i + \sum_{h}^{m} \theta_{kh} \ln Z_h \right) + \frac{\sum_{i=1}^{5} \delta_{ik}}{S_y} \tag{21}$$

Finally, the profit elasticities are defined as:

$$\frac{\partial \ln \pi^*}{\partial \ln P_i^*} \quad \text{and} \quad \frac{\partial \ln \pi^*}{\partial \ln Z_k} \tag{22}$$

for the elasticity of profit with respect to changes in input prices and for the profit elasticity with respect to changes in fixed inputs respectively.

2.4 The study area, data sources and variables

The study area consisted of the Machakos and Makueni Districts, which constitute the main marginal districts of Kenya. Exotic dairy production is fairly established in these districts and the majority of smallholder producers have organised themselves into dairy cooperatives, making it convenient to sample farmers using cooperative registers. In general, small-scale dairy farmers in the marginal zones are often neglected in policy making and in the planning of extension and dairy development programmes. The constraints and the production potential of the marginal zones are rarely investigated and understood even by the professionals. This study focuses on the marginal zones with a view to developing suitable interventions to enhance dairy expansion in these areas.

The study used cross-sectional data from an intensive farm survey of smallholder dairy producers conducted from June to September 2006 in five dairy cooperative societies in the marginal zones of Machakos and Makueni Districts. Information gathered included both quantitative and qualitative data for dairy inputs, outputs, social capital and the various forms of infrastructure. A total of 285 dairy farms out of 891 in all the five societies were selected for the study. The survey data collected was then used to create the appropriate variables for each of the three analytical models used (Kavoi, 2007).

The dependent variable for the stochastic translog cost function was the natural logarithm of total variable cost. The primary independent variables were the natural logarithms of milk output, feed price, animal health price, labour wage rate, quantity of farm-produced feeds and grazing area. The independent variables for the inefficiency model were shown in Table 1.

The translog cost function systems analysis had the translog cost function plus six input demand equations as a system. The dependent variable for the translog cost function was the natural logarithm of the total variable cost of production. The independent variables were as shown in Table 5. The six input demand equations were for protein feed, roughage feed, tick control, treatment administration, and labour input and own produced feed. The dependent variables of these input demand equations were the respective expenditure shares.

The translog profit function systems analysis had the translog profit function plus five input demand equations as a system. The dependent variable of the translog profit function was the natural logarithm of the normalised restricted profit of milk production. The independent variables were the natural logarithms of normalised price of protein feeds, normalised price of roughage feeds, normalised price of animal treatment, normalised price of tick administration, normalised labour wage rate, area of grazing, years of schooling, number of extension visits, walking distance ratio to tarmac road, number of cows and distance to the water point (Table 8). The five factor demand equations were for protein feeds, roughage feeds, animal treatment, tick administration, and labour. The dependent variables of these input demand equations were the respective expenditure shares. The estimation results of the three approaches were discussed and compared in the following section.

3. Estimation results

The parameter estimates for stochastic cost frontier and the inefficiency model are presented in Table 1. The inefficiency index estimate for each firm was used to compute descriptive statistics for dairy establishment (Table 2). The overall mean results of cost efficiency analysis show that exotic breeds are the most efficient: Ayrshire (24.36 %), Friesians (25.08%) and Jersey (25.54%). Sahiwal (28.43%) is the best among the indigenous breeds. The cooperative societies in the marginal zones, e.g. Wamunyu (19.31%), were the most efficient (Table 3). The overall inefficiency for all the farms is 27.45%.

Table 1: Translog and Cobb-Douglas cost functional forms of stochastic frontier

Variable name	Variable label	Parameters	Translog model	Cobb-Douglas model
Stochastic frontier				
LNQNT	Constant	Bo	6.8806***	30.6632***
LNFDP	Milk output	β1	-0.1692***	-0.0032
LNHELP	Feed price	β2	0.0003	0.0006
LNWAGE	Health price	β3	0.2968***	0.0079
SQQNT	Wage	β4	1.2598***	0.0069***
SQFD	Milk output* milk output	β5	0.0308***	
SQHEL	Feed price*Feed price	β6	0.0049	
SQWAGE	Health price *Health price	β7	0.0011	
QNTFDC	Wage * Wage	β8	-1.5289***	
QNTHELC	Milk output*feed price	β9	0.0095	
QNTWAGC	Milk output*health price	β10	0.0146	
FDHELC	Milk output* Wage	β11	0.2569***	
FDWAGC	Feed price*health price	β12	0.0034	
HELWAGC	Feed price *wage	β13	-0.0463*	
QNTPRDC	Health price*Wage	β14	0.0418*	
QNTACRC	Milk output*Produced feed	β15	-0.0810***	
FDPRDC	Milk output* Grazing acres	β16	-0.0606***	
FDACRE	Feed price* produced feed	β17	-0.0005	
HELPRDC	Feed price* Grazing acres	β18	0.0099	
HELACRC	Health price* produced feed	β19	0.0044	
WAGPRDC	Health price* Grazing acres	β20	-0.0012	
WAGACRC	Wage* Produced feed	β21	0.0756*	
LNPRDFD	Wage* Grazing acres	β22	-0.0810	
LNACRE	Produced feed	β23	0.7114***	-0.0023***
SQPRDFD	Grazing acres	β24	0.7977***	-0.0018
SQACRE	Produced feed* Produced feed	β25	-1.3917***	
PRDACRC	Grazing acres* Grazing acres	β26	0.0438***	
LNQNT	Produced feed* Grazing acres	β27	0.6820***	
Inefficiency model				
Constant	Constant	δ0	6.8463**	4.2005*
AGE	Age of manager	δ1	0.0178*	0.0134*
SCHED	Years of school	δ2	0.1154**	0.1337**
SQYRED	Years of school* Years of school	δ3	-0.0087**	-0.0087**
EXPER	Dairy Experience	δ4	-0.0008	-0.0006
EXNTV	Number of Extension visits	δ5	-0.0130*	-0.0214***
NUMCOW	Number of milk cows	δ6	-0.0058	-0.0146
RECODS	Dairy Records	δ7	-0.4116**	-0.6570***
FDSTO	Feed storage	δ8	-0.4799	-0.3063
H20DS	Distance to water point	δ9	-0.0157	0.0201
CREDIT	Used Credit	δ10	-0.4251*	-0.3693*
OFARM	Off-farm employment	δ11	0.1924	0.0562
WLKMODR	Walking distance to tarmac ratio	δ12	0.6002**	0.4621**
AEZ	Agro-ecological zone	δ13	-1.2248***	-0.9888***

Table 1 (continued)

Variable name	Variable label	Parameters	Translog model	Cobb-Douglas model
Variance parameters				
Lambda	Lambda = σ_u / σ_v	λ	3.6999***	2.0809***
Sigma	Sigma = $\sqrt{(\sigma_v^2 + \sigma_u^2)}$	σ^2	1.7922***	2.3938***
Sigma(v)	Sigma(v)	σ_v	.46761	1.03683
Sigma(u)	Sigma(u)	σ_u	1.73013	2.15758
Sigma-squared (v)	Sigma-squared (v)	σ_v^2	.21866	1.07501
Sigma-squared (u)	Sigma-squared (u)	σ_u^2	2.99334	4.65515
Gamma	Gamma	γ	0.9319	0.8124
Log likelihood	Log likelihood		-389.2387	-565.7207
Cost efficiency	Cost efficiency		27.4501%	12.0452%

Source: Sample survey of dairy households, June-September, 2006
** Significant at 10% level (p< 0.10)*
*** Significant at 5% level (p<0.05)*
**** Significant at 1% level (p<0.001)*

Table 4 reports the estimated marginal effects of institutional and socio-economic factors on cost inefficiency. The results show that older farmers, education above eight years of primary school and longer walking distances to the tarmac road are associated with high cost inefficiency, whereas the number of extension visits, keeping of dairy records, use of credit and the lowland transitional zone are associated with low cost inefficiency. The marginal effects results show that various institutional and socio-economic factors would reduce average cost inefficiency: use of dairy records (11.82%), storage of feeds (14%), use of credit (12.58%), whereas a 1% reduction in walking distance ratio to the tarmac road reduces cost inefficiency by 17.76%. These findings seem to point out the need for improving institutional and socio-economic setups for the purpose of enhancing resource-use efficiency.

The parameter estimates for the production structure are shown in Table 5. These estimates where then used to compute factor elasticities. The input demand elasticity estimates (Table 6) show that most of the inputs are significant complements. Overall, feed price elasticities are elastic. Protein feeds-roughage feeds, protein feeds-own produced feed, roughage feed-own produced feed and animal treatment-tick control are substitutes. All the other inputs are complements. The results on uptake of protein feeds versus roughages show that a 1% increase in price of protein feeds results in a 2.50% increase in roughage feeds and a 2.85% increase in own produced feeds. However, a 1% increase in price of roughage and own produced feeds results in a decrease in protein feeds by -2.59% and -3.51% respectively. Thus, farmers

Table 2: Mean cost reduction by range and breed

Breed	CI category	Percentage of farms	CI percentage
Frisian	< 20	50.00	8.01
	20-39	25.00	29.74
	40-59	16.89	48.53
	60-79	8.11	67.11
	80-99		
	Overall mean	100.00	25.08
Ayrshire	< 20	50.00	10.14
	20-39	30.77	29.35
	40-59	15.38	47.21
	60-79	3.85	77.86
	80-99		
	Overall mean	100.00	24.36
Guernsey	< 20	37.50	14.72
	20-39	50.00	33.49
	40-59		
	60-79	12.50	63.25
	80-99		
	Overall mean	100.00	30.17
Jersey	< 20	33.33	12.66
	20-39	50.00	27.41
	40-59	16.67	45.69
	60-79		
	80-99		
	Overall mean	100.00	25.54
Sahiwal	< 20	47.83	12.71
	20-39	30.43	31.82
	40-59	13.04	50.61
	60-79	8.70	69.77
	80-99		
	Overall mean	100.00	28.43
Boran	< 20	10.00	16.35
	20-39		
	40-59	80.00	52.47
	60-79	10.00	66.99
	80-99		
	Overall mean	100.00	50.31
Zebu	< 20	14.29	17.41
	20-39	57.14	28.39
	40-59	14.29	59.62
	60-79	14.29	64.58
	80-99		
	Overall mean	100.00	36.46

Table 2 (continued)

Breed	CI category	Percentage of farms	CI percentage
Zebu Cross	< 20	33.33	6.11
	20-39	13.33	31.55
	40-59	46.67	50.17
	60-79		
	80-99	6.67	81.11
	Overall mean	100.00	35.06
All Breeds	< 20	44.71	9.15
	20-39	27.84	29.74
	40-59	19.61	49.52
	60-79	7.45	67.80
	80-99	0.39	81.11
	Overall mean	100.00	27.45

Source: Sample survey of dairy households, June-September, 2006.

find it easier to substitute protein feeds that are of a high quality with roughage feeds and own produced feed, which are usually of poor quality. This finding leads to the conclusion that, with rising prices of protein feeds, the dairy farmers would have a greater tendency to purchase less protein feeds and to use own produced feeds, which are of poor quality. In addition, farmers seem to purchase small quantities of protein feeds just to complement roughage and own produced feeds. The elasticity of substitution confirms that these feeds are Morishima substitutes (Table 7).

The results of scale economies show that dairy production experiences scale diseconomies. The scale economy factor is 0.269, which implies that every 1% increase in milk output would lead to an increase in variable costs by 0.269%.

Table 8 shows the parameter estimates of the supply response analysis that were used to compute input elasticity estimates in relation to supply. The output response of farmers to increases in the milk price is found to be positive, as expected, and elastic i.e. 8.45 %. The percentage increase in demand for variable inputs associated with 1% increase in raw milk is: protein feeds (18.35), roughage feeds (5.43), tick control (27.25), animal treatment (9.26) and labour (7.71). Also, profit increases by 6.92% for every 1% increase in milk output price.

Table 3: Mean cost reduction by milk cooperatives

Milk society	CI category	Percentage of farms	CI percentage
UM- cooperatives			
Kilungu	<20	24.32	11.71
	20-39	29.73	29.46
	40-59	35.14	49.08
	60-79	10.81	69.29
	80-99		
	Overall mean	100.00	36.34
Kikima	<20	12.20	14.62
	20-39	46.34	30.23
	40-59	24.39	50.64
	60-79	17.07	64.43
	80-99		
	Overall mean	100.00	39.14
Marginal cooperatives			
Masii	<20	64.71	8.58
	20-39	21.18	29.20
	40-59	10.59	49.98
	60-79	3.53	66.70
	80-99		
	Overall mean	100.00	19.38
Wamunyu	<20	67.31	9.38
	20-39	21.15	29.02
	40-59	7.69	50.94
	60-79	1.92	71.83
	80-99	1.92	81.11
	Overall mean	100.00	19.31
Makueni	<20	25.00	6.44
	20-39	30.00	30.69
	40-59	35.00	48.43
	60-79	10.00	72.00
	80-99		
	Overall mean	100.00	34.96
All societies	<20	44.71	9.15
	20-39	27.84	29.74
	40-59	19.61	49.52
	60-79	7.45	67.80
	80-99	0.39	81.11
	Overall mean	100.00	27.45

Source: Sample survey of dairy households, June-September, 2006.

The response of changing input prices show that the estimated own-price elasticities of demand for variable inputs are negative. The own elasticities of animal feeds and labour are price-elastic and statistically significant. The cross-price elasticities show that all the coefficients except that of roughage price and tick control, and tick price and roughage feeds are negative. They range from -5.51 for protein feeds-roughage price to -0.06 for roughage feed demand-treatment coefficient. Thus, most of the inputs in dairy production are complements; they tend to be used together in production. But tick demand-roughage price and roughage demand-tick control price are substitutes with coefficients of 6.46 and 0.49 respectively. A possible explanation for this finding is that if, prices of roughage feeds go up, the quantity of roughage demanded goes down. This is because most of the farmers opt to graze their cows. The marginal zones have higher incidences of ticks than the high-potential zones due to the hot climate. Since cattle ticks are on grass fields, the higher the frequency of grazing, the higher the incidence of ticks. Hence, the two are substitutes. All cross-price elasticities are elastic, except for roughage demand-tick price and labour wage coefficients, and tick control demand–treatment price coefficients. These elasticities are also significant except treatment price and labour wage coefficients in roughage feed demand, treatment price coefficient in tick control demand and roughage price and tick price coefficients in demand for treatment. In sum, changes in market prices, whether input or output prices significantly affect resource use and raw milk supply although the impact in quantitative terms for tick and treatment prices in some of the input demand cases are relatively muted.

Table 4: Marginal effects of the inefficiency variables

Variable label	Parameter	Coefficient	Marginal effects	Percentage change in CI
Age of manager	δ_1	0.0178*	0.0053	0.5269
Years of school	δ_2	0.1154**	0.0342	3.4157
Years of school* Years of school	δ_3	-0.0087**	-0.0023	-0.2253
Dairy experience	δ_4	-0.0008	-0.0002	-0.0237
Number of extension visits	δ_5	-0.0130*	-0.0038	-0.3816
Number of milk cows	δ_6	-0.0058	-0.0017	-0.1717
Dairy records	δ_7	-0.4116**	-0.1182	-11.8186
Feed storage	δ_8	-0.4799	-0.1420	-14.2045
Distance to water point	δ_9	-0.0157	-0.0046	-0.4647
Used credit	δ_{10}	-0.4251*	-0.1258	-12.5826
Off-farm employment	δ_{11}	0.1924	0.0569	5.6948
Walking distance to tarmac ratio	δ_{12}	0.6002**	0.1777	17.7651
Agro-ecological zone	δ_{13}	-1.2248***	-0.3076	-30.7581

Source: Sample survey of dairy households in the marginal zones of Kenya, June-September, 2006.
(.) means the figure is negative
** Significant at 10% level (p< 0.10)*
*** Significant at 5% level (p<0.05)*
**** Significant at 1% level (p<0.001)*

An amplified picture emerges in terms of the role of fixed inputs which are the institutional and socio-economic factors included in the translog profit systems model approach (Table 9). Most of the estimated parameters associated with these variables have the expected signs. It is also observed that the majority of these non-price factors are statistically significant and have relatively large elasticity coefficients compared to market price factors. A panoramic view of the elasticity coefficients seems to indicate that dairy expansion in the marginal zones is more responsive to institutional and socio-economic non-price factors than to the market price factors.

Table 5: Estimated coefficients of the translog cost function

Variable description	Parameters	Parameter	Standard error	|b/St.Er.|	P[|Z|>z] |
Constant	α_0	-38.318488	36.0233	-3.8400	0.0001
Milk output	α_Q	3.717104	8.6980	0.4270	0.6691
Protein feeds price	α_P	-0.030767	0.0115	-2.6740	0.0075
Roughage feeds price	α_R	0.755854	0.0553	13.6720	0.0000
Treatment price	α_H	0.039231	0.0098	3.9880	0.0001
Tick price	α_T	0.582107	0.0278	20.9730	0.0000
Produced feed price	α_O	0.139173	0.0190	7.3140	0.0000
Output*Output	β_{QQ}	3.730359	1.0845	3.4400	0.0006
Protein price*Protein price	β_{PP}	0.000161	0.0000	5.5900	0.0000
Roughage price*Roughage price	β_{RR}	0.078409	0.0067	11.7890	0.0000
Treatment price*Treatment price	β_{HH}	0.000032	0.0000	3.0310	0.0024
Tick price*Tick price	β_{TT}	0.000828	0.0001	15.3470	0.0000
Produced feed price*Produced feed price	β_{OO}	0.000082	0.0001	1.1760	0.2396
Output*Protein price	β_{QP}	0.025507	0.0019	13.3690	0.0000
Output*Roughage feeds price	β_{QR}	-0.071647	0.0067	-10.6610	0.0000
Output*Treatment price	β_{QT}	-0.000261	0.0013	-0.2070	0.8358
Output*Tick price	β_{QT}	-0.069282	0.0035	-19.8640	0.0000
Output*Produced feed price	β_{QO}	0.012132	0.0029	4.1550	0.0000
Protein price*Roughage feeds price	β_{PR}	0.000058	0.0000	1.2470	0.2124
Protein price*Treatment price	β_{PH}	0.000002	0.0000	0.2000	0.8414
Protein price*Tick price	β_{PT}	-0.000007	0.0000	-0.3350	0.7377
Protein price*Produced feed price	β_{PO}	-0.000052	0.0000	-1.5930	0.1111
Roughage feeds price*Treatment price	β_{RH}	-0.000099	0.0000	-1.9770	0.0481
Roughage feeds Price*Tick price	β_{RT}	0.001674	0.0001	11.3490	0.0000
Roughage feeds Price*Produced feed price	β_{RO}	-0.000544	0.0001	-6.2980	0.0000
Treatment price*Tick price	β_{HT}	-0.000052	0.0000	-2.9780	0.0029
Treatment price*Produced feed price	β_{HO}	0.000022	0.0000	1.4300	0.1526
Tick price*Produced feed price	β_{TO}	-0.000266	0.0000	-7.8360	0.0000
Output*Acres	β_{OA}	-0.100364	0.1139	-0.8810	0.3782
Protein feeds price*Acres	β_{PA}	0.000059	0.0000	2.1330	0.0329
Roughage feeds Price*Acres	β_{RA}	0.000058	0.0000	1.3580	0.1745
Treatment price*Acres	β_{HA}	0.000003	0.0000	0.3820	0.7026
Tick price*Acres	β_{TA}	0.000044	0.0000	2.2900	0.0220
Produced feed price*Acres	β_{OA}	-0.000071	0.0000	-1.8310	0.0671
Dairy acres	β_A	-1.160007	0.5610	-2.0680	0.0387

Dairy acres*Dairy acres	β_{AA}	1.238200	0.6218	1.9910	0.0465

Source: Sample survey of dairy households in the marginal zones of Kenya, June-September, 2006.

Table 6: Estimated price elasticities of the translog cost function

Input items	Protein feeds demand	Roughage feeds demand	Demand for animal treatment	Demand for tick adminis-tration	Labour demand	Own produced feeds demand
Protein feed price	**-2.328412*** (0.023576)**	2.502541 (3.599495)	-2.111929 (7.704242)	-4.285899 (4.859472)	-4.318605 (18.898211)	2.850351 (8.870101)
Roughage feed price	-2.593648 (3.395439)	**-1.151118*** (0.615729)**	-2.523465 (5.45141)	-1.585368 (8.416966)	-3.807824 (10.19960)	0.151054 (5.104626)
Animal treatment price	-4.041275 (7.580561)	-0.494424 (9.071102)	**-1.765213 *** (0.642758)**	3.189816*** (0.011132)	-8.595361 (5.619736)	-3.081924*** (0.009220)
Tick administra-tion price	-3.760632*** (0.0100265)	-1.202651*** (0.0097723)	3.253751 *** (0.011118)	**-2.208417*** (0.0209993)**	-8.278418*** (0.798226)	-4.084581*** (0.044306)
Wage rate	-6.071546 (14.576002)	-1.323139 (7.496768)	-1.956414 (4.589133)	-2.851511 (4.589143)	**-2.275161*** (7.334627)**	-4.525273 (5.735175)
Price of own feeds	-3.507752*** (0.048182)	0.706697** (0.311899)	-3.426819*** (0.534294)	-3.472315*** (0.011132)	-4.071378*** (0.0403235)	**-1.714289*** (0.005386)**

Source: Sample survey of dairy households, June-September, 2006
**** Significance at 1% level*
*** Significance at 5% level*

Table 7: Morishima elasticities of substitution between inputs

Input demand for:	Protein feeds	Roughag e feeds	Animal treatment	Tick adminis-tration	Labour	Own produced feeds
Protein price	0.000000	3.653660 (3.403474)	-2.416174 (5.997019)	-4.144257 (9.76605)	-2.043444 (2.171492)	4.564641 (12.08077)
Roughage price	-2.627246 (4.2869678)	0.000000	-2.827709 (9.0245)	-1.443726 (6.45409)	-1.532663 (8.546130)	1.208730 (2.22717)
Animal treatment price	-3.744766 (7.584213)	-1.697811 (9.99510)	0.000000	3.331458 (6.45409)	-6.320201 (6.580149)	-1.367634 (3.729386)
Tick administration price	-2.897893 (9.669783)	-2.406037 (3.403474)	-3.491221 (4.085834)	0.000000	-6.003257 (7.456149)	-2.370291 (3.729386)
Wage rate	-2.452006 (2.35619)	-0.496689 (9.99510)	-3.731063 (4.085834)	-7.347838 (8.45409)	0.000000	-2.810983 (3.735649)
Own feeds price	-3.374905 (8.252961)	-5.85186 (5.38439)	-2.306262 (4.093386)	-2.709868 (4.607802)	-1.796217 (6.342800)	0.000000

Source: Sample survey of dairy households, June-September, 2006.

4. Conclusions and policy implications

In conclusion, therefore, the results of the three analytical approaches are interrelated. The supply response analysis and cost-factor demand analysis show that farmers are responsive to market price factors. This implies that any price policy designed to stimulate supply would be expected to have a positive response. The results of the stochastic cost frontier indicate that the institutional and socio-economic factors have a significant effect on the reduction of inefficiencies. Simultaneously, the results of the systems analysis show a greater responsiveness of producers to institutional and socio-economic factors than to market price factors. Thus, either the price factors or non-price factors or both can be used as policy levers to influence the expansion of dairy production in the marginal zones and in the country as a whole.

The responsiveness to market price factors can be attributed to the policy of liberalisation, which resulted in decontrol of prices in the dairy industry in 1993. However, much more can still be done within the liberalised market environment to influence prices and stimulate output supply. For example, there is need to ensure that the livestock-manufacturing feed markets are efficient. Also, the government can lower the import duties on imported feed ingredients in an effort of making livestock feeds affordable for farmers. In addition to price decontrols, a further liberalisation of the output markets would be expected to stimulate supply response. For example, removing the multiple indirect taxes on farmers' income would tend to increase milk prices. Also, there is a need to reduce the direct tax rate on farmer' profits, which stands at 16%.

The improvement of institutional and socio-economic setups needs public sector response. Judicious investments in physical and institutional infrastructure that has public good attributes should be undertaken in the marginal zones. Development of physical and institutional infrastructure in rural areas is self-reinforcing; it is necessary for reducing transaction and production cost inefficiencies, thereby increasing access to production resources and markets by smallholder farmers. Ultimately, it enhances efficiency in input and output markets. However, it requires the enhancement of public expenditure on rural road infrastructure and its management, rural water supply, extension and credit services, farm records, animal feed storage systems, as well as other agricultural support services. In summary, since farmers in a technically developing dynamic agriculture depend much more on the use of purchased inputs, all the related farm support systems must also adjust continuously to new demands.

In summary, the area of public policy and management is the primary challenge facing Kenya if agricultural production is going to develop into prosperous economies in the rural marginal areas. The government remains the major player in promoting agricultural production, and particularly the development of smallholder dairy, even in a liberalised market economy. The policy interventions identified in this study require major public development expenditures. However, such expenditures should be viewed as part of the ongoing development strategy to alleviate poverty in the rural areas.

Table 8: Restricted parameter estimates of the translog profit function of dairy farms

Variable description	Parameters	Coefficient	Standard error	|P[|Z|>z] |
Constant	α o	8.989821	1.241105	0.000000
Ln protein feeds price	α1	-0.603825	0.297183	0.042200
Ln roughage feeds price	α 2	-0.036735	0.170419	0.829300
Ln tick administration price	α3	-0.271030	0.732737	0.711500
Ln treatment administration price	α 4	-0.789021	0.319692	0.013600
Ln wage rate	α5	-0.233614	0.603504	0.698700
Ln grazing acre	α6	-1.495437	0.431893	0.000500
Ln school years	α7	-0.006535	0.078428	0.933600
Ln extension	α8	0.257622	0.177241	0.146100
Ln walking ratio	α9	-4.487264	1.287484	0.000500
Ln number of cows	α10	0.959776	0.320285	0.002700
Ln water distance	α11	0.148062	0.299153	0.620600
Squared protein price	β1	0.115604	0.084319	0.170400
Squared roughage price	β2	-0.245191	0.052533	0.000000
Squared tick price	β3	-0.065500	0.228337	0.774200
Squared health price	β4	0.051228	0.091619	0.576100
Squared labour price	β5	-0.896960	0.412682	0.029700
Squared grazing area	β6	0.073087	0.073303	0.318700
Squared education	β7	-0.001652	0.005043	0.743200
Squared extension visit	β8	0.000364	0.001387	0.792800
Squared walking ratio	β9	4.018325	1.241972	0.001200
Squared water distance	β10	0.167444	0.076835	0.029300
Squared number of cows	β11	-0.022844	0.012975	0.078300
Protein–roughage cross	γ12	0.013699	0.036985	0.711100
Protein–tick cross	γ13	-0.019718	0.159879	0.901800
Protein–health cross	γ14	0.069487	0.055478	0.210400
Protein–labour cross	γ15	0.026122	0.117528	0.824100
Protein–acre cross	γ16	0.102993	0.052811	0.051200
Protein–education cross	γ17	-0.000679	0.000414	0.100900
Protein–extension cross	γ18	-0.001075	0.000984	0.274700
Protein–walking ratio cross	γ19	0.358633	0.206266	0.082100
Protein–water cross	γ110	0.001302	0.001001	0.193300
Protein–cow cross	γ111	-0.062775	0.033157	0.058300
Roughage–tick cross	γ23	-0.140243	0.092579	0.129800
Roughage–health cross	γ24	0.096508	0.046047	0.036100
Roughage–labour cross	γ25	0.457543	0.102389	0.000000
Roughage–acre cross	γ26	0.167387	0.057924	0.003900
Roughage–education cross	γ27	0.027169	0.009930	0.006200
Roughage–extension cross	γ28	-0.000670	0.000516	0.194300
Roughage–walking ratio cross	γ29	-0.258326	0.111833	0.020900
Roughage–water cross	γ210	0.000068	0.000639	0.914800
Roughage–cow cross	γ211	-0.081451	0.030583	0.007700

Table 8 (continued)

Variable description	Parameters	Coefficient	Standard error	|P[|Z|>z] |
Tick–health cross	γ34	0.117520	0.108906	0.280500
Tick–labour cross	γ35	0.642770	0.393242	0.102100
Tick–acre cross	γ36	0.073562	0.096569	0.446200
Tick–education cross	γ37	0.031913	0.026506	0.228600
Tick–extension cross	γ38	-0.097453	0.049646	-1.963000
Tick–walking ratio cross	γ39	0.165843	0.288438	0.575000
Tick–water cross	γ310	0.030487	0.127103	0.240000
Tick–cow cross	γ311	0.110306	0.060026	1.838000
Health–labour cross	γ45	-0.199206	0.098832	-2.016000
Health–acre cross	γ46	0.149267	0.069448	2.149000
Health–education cross	γ47	0.000712	0.000697	1.022000
Health–extension cross	γ48	-0.004447	0.032145	-0.138000
Health–walking ratio cross	γ49	0.508210	0.165169	3.077000
Health–water cross	γ410	0.000284	0.000763	0.373000
Health–cow cross	γ411	-0.004060	0.029705	-0.137000
Labour–acre cross	γ56	-0.621628	0.186586	-3.332000
Labour–education cross	γ57	0.010407	0.051376	0.203000
Labour–extension cross	γ58	-0.027267	0.095122	-0.287000
Labour–walking ratio cross	γ59	0.317950	0.496114	0.641000
Labour–water cross	γ510	0.128672	0.183447	0.701000
Labour–cow cross	γ511	0.404881	0.224587	1.803000
Acre–education cross	γ67	0.011891	0.013828	0.860000
Acre–extension cross	γ68	-0.011163	0.015563	-0.717000
Acre–walking ratio cross	γ69	0.414144	0.140919	2.939000
Acre–water cross	γ610	0.136515	0.066034	2.067000
Acre–cow cross	γ611	-0.031341	0.038518	-0.814000
Education–extension cross	γ78	-0.012071	0.004868	-2.480000
Education–walking ratio cross	γ79	0.053685	0.029175	1.840000
Education–water cross	γ710	-0.026380	0.021393	-1.233000
Education–cow cross	γ711	0.007561	0.007185	1.052000
Extension–walking ratio cross	γ89	-0.201538	0.051056	-3.947000
Extension–water cross	γ810	-0.037334	0.037635	-0.992000
Extension–cow cross	γ811	0.001096	0.006220	0.176000
Walking ratio–water cross	γ910	-0.074148	0.196242	-0.378000
Walking ratio–cow cross	γ911	-0.105894	0.094721	-1.118000
Water distance–cow cross	γ1011	-0.056501	0.080284	-0.704000
Value of log-likelihood function		-701.8500		
Number of observations		134		

Source: Sample survey of dairy households, June-September, 2006

Table 9. Estimated elasticities of translog profit function

Price/non-price factors	Supply of output	Protein feed demand	Roughage feed demand	Tick control demand	Demand for treatment	Labour demand	Profit
Milk price	8.447485*** (0.533667)	18.347659*** (1.307477)	5.432767*** (0.623327)	27.257184*** (8.059742)	9.265917*** (1.049491)	7.707584*** (0.700465)	6.918932
Protein price	-2.879365*** (0.205187)	**-12.040894*** (1.402061)**	-2.628464*** (0.668410)	-3.131430*** (1.085261)	-3.298629** (1.125412)	-2.568353*** (0.751137)	-2.449679
Roughage price	-1.788385*** (0.205187)	-5.513481*** (1.40206)	**-2.531603*** (0.160051)**	6.463743*** (2.069521)	-1.086187 (2.89088)	-0.435301** (0.179860)	-7.157872
Tick price	-0.693921*** (0.205187)	-3.045531*** (0.335724)	0.499888*** (0.160051)	**-0.887787 (1.186758)**	-1.387115 (1.657767)	-1.113368 *** (0.103140)	-1.894087
Treatment price	-0.828031*** (0.205187)	-3.109499*** (0.192519)	-0.060135 (0.091780)	-0.993004 (1.186758)	**-1.533677 (7.127792)**	-2.487860*** (0.443464)	-3.501132
Wage rate	-2.257781*** (0.205187)	-4.794048)*** (0.827764)	-0.387358 (0.394623)	-3.053444*** (0.640728)	-2.904201*** (0.664433)	**-2.174771*** (0.193483)**	-6.952917
Grazing area	21.021097*** (1.159037)	9.034304*** (1.719896)	-1.437736 (3.010899)	14.024740*** (3.449379)	8.001091*** (1.731764)	6.876338*** (2.134441)	0.388837
Education	18.307972*** (1.096135)	8.671277*** (1.704290)	5.529701*** (2.102129)	-2.302677 (3.437349)	-8.801970*** (3.548885)	4.379563** (2.119354)	-0.882147
Extension visits	16.420333*** (1.086064)	11.688364*** (1.869561)	9.407854*** (2.176565)	1.071799 (3.411535)	-11.065347*** (3.518724)	8.068382*** (2.191360)	-0.57402
Walking ratio	-8.941067*** (1.061337)	-15.62046*** (1.582917)	-16.67541*** (2.13471)	2.885449 (3.003671)	-21.558419*** (3.712371)	22.499677*** (2.110016)	-1.661317
Distance to water	-7.771938*** (1.924270)	0.131763 (1.582917)	-0.573232 (2.265803)	19.972109*** (3.099519)	5.685312* (3.197629)	25.078464*** (2.108403)	-1.661536
Number of cows	31.692338*** (1.151324)	22.831561*** (1.777083)	20.940891*** (1.9302676)	15.575116*** (3.065945)	6.808985* (3.17060)	20.553733*** (1.941779)	1.99814

Source: Sample survey of dairy households, June-September, 2006

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