Measuring Cost Efficiency in Smallholder Dairy: Empirical Evidence from Northeast Thailand

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Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, July 24-27, 2005.

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Abstract

This paper investigates smallholder dairy competitiveness from estimates of a translog cost frontier using data from 130 smallholder dairy farms in six provinces of Northeast Thailand. Cost efficiency estimates indicate that there is significant scope for improving cost efficiency in smallholder dairy farms in Northeast Thailand, and costs can be reduced by 26 percent on average. The empirical results also strongly suggest that smaller farms are more cost efficient than larger ones within this sample of smallholder dairy farms. Proper herd management for maintaining an optimal milking cows-herd size ratio coupled with yield-enhancing technologies can enhance cost efficiency. Feed technology options that can potentially reduce costs while maintaining yield levels may also have potential for doing so but the empirical evidence on this is weak, suggesting a gap between technology dissemination and successful adoption. Further validation may be needed towards adjustment in the technology to suit the varying circumstances and resources of smallholder dairy systems. Innovations for strengthening extension modalities and their delivery systems may also need to be explored to enhance the long-term viability of smallholder dairy systems.

Keywords: cost efficiency, smallholder dairy, feed technology innovations

Smallholder dairy competitiveness is being threatened by the increasing competition in a rapidly globalizing market for milk and milk products. There is a growing concern among smallholder dairy producers that with increasing prices of imported feed ingredients (e.g., soya meal and corn) causing cost of production to continuously rise under current productivity levels, their profit margins are being squeezed so that their competitiveness will be eroded in the absence of any interventions to reduce production costs. In Thailand, where smallholder dairy production has been successfully promoted as a livelihood option in mixed farming systems, the reduction of tariffs for milk and milk products from its current levels of 5-30% to 0% in year 2015-2025 will likely increase the supply coming from imports of such commodities, putting domestic producers in close competition with their foreign counterparts. The policy challenge for the Thai government under these circumstances is to ensure that the millions of smallholder dairy farmers are not kept out of the one livelihood opportunity that has generated incomes and employment in rural Thailand. The competitiveness of smallholder dairy farms hinges on their ability to keep production costs low. Since feed costs account for about two-thirds of total costs in dairy production, options to reduce feed costs and improve cost efficiency would have significant impact on enhancing competitiveness. Therefore, analysis of ways in which producers can improve cost efficiency via cost-reducing feed technologies, for example, can provide valuable insights for effective smallholder dairy development policymaking.

The goal of this article is to empirically investigate cost-efficiency in smallholder dairy farms using a dataset obtained from a survey in Northeast Thailand, and identify the determinants of inefficiency. This is done through the estimation of a stochastic cost frontier. Cost-efficiency is analyzed across farms according to their feeding management (i.e., types of feeds used), in order to assess the efficiency effects of utilization of local resources-based homemade feed concentrates vis-à-vis commercially produced concentrates.

The article is organized as follows: Sections 1 briefly discusses issues about smallholder competitiveness in dairy production and section 2 presents some technology options for specifically addressing some feed cost issues. We describe the survey data used and present some descriptive results from the survey in section 3. The analytical framework is presented in section 4, followed by the empirical specification in section 5, and findings from empirical estimation in sections 6 and 7. Section 8 concludes and discusses the policy implications of the findings.

Can smallholder dairy be competitive?

The survival of small dairy farms hinges upon the competitiveness of those farms with the larger dairy farms, and the long-run competitiveness in a generic commodity market like milk depends upon low cost production (Tauer 2001). There are two components of the cost of production for an individual farm, as identified by Tauer (2001). First is the lowest cost for the given technology and practices which the farmer uses, and this can be referred to as the best practice of frontier cost curve. The second component of cost is how efficient that individual farm is in using appropriate techniques at the given farm size. Costs can be greater than the best practice costs if a farmer is inefficient in using the best practice techniques. Empirical findings from Tauer (2001) indeed suggest that efficient small dairy farms can be cost competitive with larger farms, while less efficient small farm neighbors may not be. The issue then is to identify in what ways those small dairy farms could be assisted to become more efficient.

Studies have shown empirical evidence suggesting that smallholder dairy producers remain competitive in many areas. Staal et al. (2003) reported that local competitiveness is supported by several key factors, including low opportunity costs of labor and the ability of small mixed farms to capture more efficiently the value of nutrient cycling. The study of de Jong (1996) also suggested that in some cases, countries with mainly smallholder dairy production could compete internationally. This could be attributed to the advantages of integrating dairy production into crop systems as crop-livestock farmers, compared to pastoralists and agro-pastoralists, have more control over feed inputs, and are able to capture complementarities in feed resource use and nutrient cycling, which increase overall farm efficiency and reduce vulnerability to market shifts.

Jong (undated), in his study on efficiency analysis of small dairy farms in Korea, also revealed that the most efficient dairy farm had the highest level of income per head and applied lower quantities of concentrate feeding and family labor hours. The optimal rate of application of concentrate feeding and family labor hours was much lower than the general rates of applications on dairy farms. In order to increase the efficiency of dairy farm production and the level of farm income, he suggested that the application of concentrate feeding and family labor hours must be decreased from present level of application rates. This would have added benefit of increasing fertility of dairy cows by reducing concentrate feeding, farmyard manure and improving the quality of the rural environment.

Devendra (2002) also pointed out that the smallholder dairy farms that collapsed during the Asian economic crisis were those that were largely dependent on the use of imported feeds, notably maize and supplements. Since feed concentrates are expensive, Pichet (undated) stressed that the government must make serious efforts to reduce the costs of milk production through better utilization of pastures and fodder crops. Indeed with the inevitable liberalization of tariffs and quotas for dairy and dairy products, domestic dairy producers must take the needed steps towards improving their efficiency and productivity in order to be able to compete with products from low-cost dairy producing nations.

Innovations in feed technology to improve cost efficiency

According to Pichet (undated), a great deal of basic scientific evidence from many developed dairy producing countries have shown that animal performance, especially milk production, is much more dependent on the quantity and quality of feed eaten rather than on the genetic make up of the animal. Hence, feeding management is an essential aspect of productivity and cost-efficiency improvement goals in dairy. The development and use of local feed resources such as cassava as main ingredient for feed concentrate was identified as a potentially promising technology response to the need to find alternative feed technology options that could lower feed costs, which accounts for the bulk of dairy production cost. Cassava prices are lower than corn and soya prices per feeding value unit in Thailand. Cassava is the cheapest source of starch by weight in Southeast Asia. Cassava has been a major export crop in Thailand, largely to the EU, in the form of chips and pellets for use as animal feed as well as in the form of starch and flour. When the EU imposed import quotas for cassava during the 1990s, world prices for this commodity drastically declined, putting the livelihoods of many Thai cassava farmers in jeopardy. This provided the impetus for the Thai government to encourage alternative use of cassava domestically in order to cushion the negative economic impact of the contraction of its main export market.

Due to the insufficient availability of protein forages grown on farm, cassava hay from cassava foliage plays a crucial role as a protein supplement in smallholder dairy systems in the northeast of Thailand. In addition, cassava roots provide low-cost energy sources compared to alternatives such as corn. Homemade feed concentrate such as cassava-based homemade concentrate is aimed more at reducing costs than increasing milk yield since it uses locally available feed resources. Investigating the economic viability and demand for this feed technology in smallholder dairy systems in northeast Thailand would be useful in identifying the critical factors that could be addressed via identified options in order to facilitate widespread adoption by those who most need it.

Data and Descriptive Statistics

A structured survey of 130 smallholder dairy farmers in six provinces (namely, Khon Kaen, Udon Thani, Sakon Nakhon, Mahasarakham, Loei and Nongbualamphoo) of the upper part of the Northeast region of Thailand was conducted in 2004 as part of a project on improving productivity of crop-livestock systems in rainfed areas in Southeast Asia, of which Thailand was one of the six benchmark sites.[2] (See table 1 for distribution of sample respondents.) The survey obtained primary date on farmer and farm characteristics, cost of dairy production, volume and value of dairy production and utilization, feed concentrate use (type, volume, value), and farmer perceptions. Information on costs and returns pertained to dairy farm operations in 2003.

Based on survey data, farmers were classified into three groups according to the type of feed concentrate they use. Type 1 farmers are those who fed dairy cows with commercial concentrate only, whereas type 2 farmers are those who fed dairy cows with homemade feed concentrate only. Type 3 farmers are classified as those who fed dairy cows with a mixture of commercial and homemade feed concentrate in varying proportions. Homemade feed concentrate is defined as a feed concentrate using locally available feed, more commonly cassava-based, and mixed by farmers on their own farms. On the other hand, commercial feed concentrate is defined as concentrate produced and bought from feed mills.

[2] The project was funded by the Asian Development Bank under RETA 6005 and coordinated by the International Livestock Research Institute. It was implemented in five countries: Indonesia, Philippines, Thailand, Vietnam, and S. China during the period 2001-2004. Khon Kaen University was the collaborating partner in Thailand.

(insert table 1 here)

Feed concentrate use

The majority of smallholder dairy farmers in the northeast region have been using homemade feed concentrate in varying proportions of their total feed concentrate use (see table 2). It was observed that dairy farmers under the supervision of the Dairy Farming Promotion Organization of Thailand (DPO) prefer to use homemade feed concentrate compared with other dairy farmers.[3]

(insert table 2 here)

Farmers who use 100% homemade feed concentrate (type 2) or HMC mixed with commercial feed concentrate (type 3) use a variety of feed ingredients that included 24 items as shown in table 3. The major ingredients were cassava chips, soybean meal, fine rice bran, minerals, and maize. However, most of the type 3 farmers used commercial feed as a main ingredient and mixed it with other materials such as cassava chips. The prices of these major ingredients are shown in table 4. The prices of raw materials were reported to be similar across all farms. Soybean meal commanded the highest price at 14–15 baht per kg, whereas cassava chips and rice bran had the lowest price at 3.3–3.6 baht per kg on average.

(insert table 3 here)

(insert table 4 here)

Socioeconomic profile of sample respondents

[3] The DPO is a government enterprise tasked with milk production, processing, and marketing. It undertakes a number of activities to support dairy farming, such as offering crossbred heifers at cost price to newly established dairy farmers, training of farmers interested in dairy farming, providing extension services including artificial insemination, veterinary services, milk recording and farm management advice, establishing a milk collection center, and buying milk at guaranteed prices.

Most of the dairy farmers in the northeast region were smallholder farmers, i.e., having 1-10 head of milking cows. Table 5 shows the socioeconomic characteristics of the dairy farmer-respondents. The majority of the dairy farmer-respondents are in their mid-40s, with ages ranging from 31 to 60. Sixty to 80 percent of the respondents are heads of the family/household and are married. Moreover, males constitute the majority of the household members in type 1 farms, whereas types 2 and 3 farms have an almost equal number of males and females in the household. In contrast, more female members were available for household labor on the farm (57–60%) across the three types of farms surveyed. Type 2 farmers had the highest household income from all sources, whereas type 1 farmers had the lowest. This could imply either that farmer-respondents with higher income were the ones adopting the cost-reducing home-made feed concentrates more than the other farms, or that adoption may already have generated gains in terms of the relatively higher income among those observed to be adopting. This is an empirical issue of causality that will be addressed later in the discussion of the empirical findings.

(insert table 5 here)

Characteristics of smallholder dairy farms

Farm characteristics of sample farmer-respondents are shown in table 6. The average size of landholdings of type 2 farms (38.48 ha) was higher than that of type 3 (30.69 ha) and type 1 (28.15 ha), with the latter having the smallest landholdings. Type 2 farmers also owned relatively more land than type 1 and 3 farmers. Most of these lands were largely used in dairy farming activities, while the remaining areas were used for crop production.

(insert table 6 here)

Type 2 farmer-respondents had the highest average total value of farm assets (excluding land) at 196,720 baht[4]. In comparison, type 1 farmer-respondents had the lowest average total value of farm assets (56,244 baht), which is less than half of what types 2 and 3 had. Moreover, the average animal inventory of type 2 farmer-respondents was higher at 22.3 head compared with types 3 and 1, which had only 17.9 and 12.5 head, respectively. Similarly, type 2 dairy farmers also had more productive cows on average. Sources of feed were on average about 10 km from the house of the dairy farmer-respondents. A general observation can be made that type 2 farmer-respondents are better off in terms of household income and farm resources than type 1 and 3 farmers. This would imply that those dairy farmer-respondents adopting the cost-reducing homemade feed concentrate (type 2) were not resource-constrained. Conversely, results of the survey also showed that the smallholder dairy farmers using costly commercial feed concentrates were actually those with fewer available resources at their disposal.

Cost structure of dairy production

Among the three types of farmers, it was observed that type 2 farmer-respondents incurred the highest total production costs, expending about 344,010 baht per year, whereas type 3 and 1 farmer-respondents incurred costs of about 261,768 and 190,547 baht per year, respectively (see table 7). On average, all farmer-respondents in the study incurred about 275,484 baht per year for dairy production costs.

(insert table 7 here)

Cash costs constitute about 90% of the total production costs among all dairy farms. Results of the study show that feed costs accounted for 63% of the total costs on all farms on average, which is more than half of the total cost of dairy production. The cost of

[4] Exchange rate at the time of survey was US$1 = Baht 40.

roughage also accounted for a larger percentage (11%), whereas other cash cost items such as interest payments on loans and veterinary supplies and services accounted for 9% and 3% on average on all dairy farms. Other cash cost items accounted for only 1% to 2% of the total costs. There was no apparent difference in the percentages of production costs across the three types of farms.

The cost of production per unit of milk output across all farms in this study averages 8.36 baht/kg (see table 8). However, the cost of production when estimated based on productive cattle is lower than that based on nonproductive cattle: 2.79 baht/kg of milk vis-à-vis 5.57 baht/kg of milk, respectively. On average, type 2 and type 3 farms have a lower cost of production per unit output than type 1 farms in both productive and nonproductive cow-based estimates. Given that there was a relatively higher proportion of nonproductive cows than productive cows in the herd across all farms this suggests the importance of managing herd size toward an optimal mix by increasing the ratio of milking cows to herd size in order to improve cost efficiency.

(insert table 8 here)

Feeding management is also needed to effectively bring down the cost of production. With the high proportion of feed cost to total cost of dairy production (of all respondents), this suggests an opportunity to reduce production cost by lowering the feed cost. Homemade feed concentrates using locally available feed resources can potentially do so when properly applied by smallholder dairy farmers. Survey data indicate that the price of homemade concentrate is relatively high (6.01 baht/kg) because of the high variability of ingredients used in home-concentrate formulas, including high-cost ingredients such as soybean meal and corn meal. On the other hand, the cost of homemade concentrate has been found to decline to about 4.0 baht/kg by using local or on-farm feed resources such as cassava (Wanapat et al. 2000). Thus, there is potential for improving the adoption of the optimal, cost-efficient combination of local feed ingredients in homemade concentrate use by smallholder dairy farmers in northeast Thailand. This will subsequently have implications on the ability of smallholders to be competitive if they are able to attain a cost-efficient dairy production operation. Hence, it is important to investigate how well smallholders are able to attain cost-efficiency given their current levels and nature of production operations.

Measuring Cost Efficiency with the Stochastic Frontier Model

A frontier cost function defines minimum costs given output level, input prices, and the existing production technology. Because of technical and allocative inefficiencies, it is unlikely that all firms operate at the frontier. Using the stochastic frontier approach to efficiency analysis, cost efficiency can be estimated using a composed error cost frontier following Bravo-Ureta and Rieger (1991) and Schmidt and Lovell (1979):

$$C_i = C_i\,(w, y, \beta) + (v_i + u_i)\,,\ v_i \sim N(0, \sigma_v^2) \text{ and } u_i \sim |N(0, \sigma_u^2)|\,, \qquad (1)$$

where the overall error term is decomposed into v_i and u_i. Deviation from the frontier due to random events is represented by v_i. Inefficiency is captured by the one-sided distribution of u_i with higher values of u_i representing greater deviations from minimum cost (i.e., greater inefficiency). This estimation method can be implemented by assuming a distribution for the non-negative error term u_i , e.g., exponential, gamma, and half-normal distributions (see Bravo-Ureta and Pinheiro 1993).

With these specifications, it is possible to derive marginal density, mean, and variance of $e_i = u_i + v_i$. Because the residual of this procedure is e_i and not u_i the component of the error due to inefficiency is not directly observable from the estimates of the model. However, Jondrow et al. (1982) provide a convenient means by which the firm specific inefficiency term may be recovered. An expression for conditional distribution of *u* given *e* can be obtained, $f(u|e)$. Thus, estimating the cost function that incorporates e_i using either maximum-likelihood estimation (MLE) or method of moments provides estimates of the cost inefficiency term, u_i. The measure of cost inefficiency, CE_i, can be expressed as

$$CE_i = \{C_i\ (w, y, ß\ ) / E_i\ \} = E(\exp\{- u_i\}|\ e_i \qquad (2)$$

This measure provides inefficiency estimation that is limited to producer-specific estimates of the cost of inefficiency (Nadolnyak et al. 2000). Estimation of u_i can be followed by using the following equation:

$$\hat{u}_i \;=\; \square_i z_i + \square_i\,, \qquad (3)$$

where the z_i's are the variables that explain the inefficiency.

Previous studies have estimated this model using a two-stage method, consisting of Maximum-likelihood estimation of a stochastic cost frontier followed by OLS estimation of an equation relating predicted cost inefficiency to its potential determinants (see Kalirajan (1991), for example). The argument for justifying this approach is made that farm-specific factors exert only an indirect effect on production through their association with inefficiency, so their effect is appropriately modeled as a two-stage procedure. This approach has been criticized because the model of predicted inefficiency effects contradicts the assumption of identically distributed u_i's from the first stage (see Kumbhakar, Gosh and McGulkin (1991) and Reifschneider and Stevenson (1991), for example). Battese and Coelli (1995) overcame this problem by introducing a single step procedure that assumes that *ui* is distributed independently but not identically as truncations of the normal distribution. Thus, the mean of the cost inefficiency effect is a function of variables z_i. This specification permits the coefficients $\square$ to be estimated together with the coefficients of the cost frontier.

The functional forms that are most commonly used for cost frontier estimation are Cobb-Douglas and translog. The Cobb-Douglas specification is very simple and allows the focus to be on the error term (Kumbhakar and Lovell, 2000). The advantage of the translog specification over that of Cobb-Douglas is that the one-sided error component u_i now captures both input oriented technical and allocative inefficiency. Decomposing it into the two inefficiency measures requires additional data on input prices or cost shares. Derivations of the decomposed measures require the use of complex numerical techniques (Nadolnyak et a. 2000). The translog specification also provides a more flexible functional form that is a second-order approximation of the true cost function and that it exploits some information that Cobb-Douglas specification does not.

Empirical Specification

In order to analyze the cost efficiency of smallholder dairy farms in Northeast Thailand, a stochastic cost frontier approach was adopted. We consider a translogarithmic cost function to model the technology of smallholder dairy in Northeast Thailand (equation 4).

$$C_i = \square_0 + \square_y Y_i + \square_k K_i + \sum_j \square_j P_{ji} + ½ \sum_j \sum_s \square_{js} P_{ji} P_{si} \qquad (4)$$

$$+ ½ \square_{yy} (Y_i)^2 + ½ \square_{kk} (K_i)^2 + \sum_j \square_{jy} P_{ji} Y_i$$

$$+ \sum_j \square_{jk} P_{ji} K_i + \square_{yk} Y_i K_i + v_i + u_i$$

$$j,s = F, R, L$$

where C_i is total annual cost per farm (in thousand Baht), Y_i is annual milk production per farm, P_{Fi} is the average price of feed concentrate per kg, P_{Ri} is the average price of roughage per kg, P_{Li} is the average wage rate per hour, and K_i is the value of capital stock per farm. The dependent variable and input price variables on the right-hand side were normalized by the average price of other inputs to conform to the linear homogeneity assumption.

The translog cost frontier is estimated using maximum likelihood in FRONTIER (version 4.1c) using survey data from 130 sample dairy farms in six provinces of Northeast Thailand. Since all right-hand side variables of the cost equation have been normalized by their sample means, first order coefficients can be directly interpreted as cost elasticities computed at mean values. Table 9 presents the definition and descriptive statistics of the variables used in the model.

(insert table 9 here)

Translog Cost Frontier Model Estimation Results

The stochastic cost frontier estimation based on equation (4) shows the effect of input prices and fixed factor (capital) on the total cost of dairy farms. Estimates of the translog cost frontier coefficients are shown in table 10. The results show that the cost elasticities with respect to output, input prices, and capital stock are all positive as expected, conforming to the basic properties of the cost function that satisfy the cost minimization assumption. The cost elasticities are also statistically significant at the 1% to 5% probability level. Since output elasticity is positive, this implies that an increase in milk production also necessitates an increase in total cost of dairy farms. The same results were observed for input prices and capital stock.

(insert table 10 here)

There is no strong empirical support for economies of scale as the coefficient of Y^2, while negative, is not statistically significant. Cost elasticity with respect to capital appears to indicate economies of scale, given the statistically significant negative coefficient of K^2. There is potential for decreasing cost by using a combination of feed concentrate and roughage (substitutes), as evident in the negative coefficient of the interaction of prices of roughage and feed concentrate.

Cost efficiency estimates ranged from a low of 1.02 to a high of 3.58, with an average efficiency estimated at 1.26 (see table 11). This indicates that smallholder dairy farms in Northeast Thailand are operating at 26 percent higher cost than the best practice. This also implies that, on average, 26% of the costs incurred can be avoided without any decrease in total output. Among the three types of farmer-respondents (according to their feed use), dairy farmer-respondents using purely commercial feed concentrate appeared to be the most cost-efficient, with an average efficiency estimate at 1.048 or 4.8% above the frontier efficiency level. Those using homemade feed concentrates had an average efficiency estimate of 1.254 or 25.4% above the frontier efficiency level. Dairy farmers using mixed feed concentrates appeared to be the least cost efficient, having an average efficiency estimate of 1.334 or 33.4% above the frontier efficiency level. Moreover, 68% of all dairy farms were below the mean efficiency value of 1.26, implying that more than half of the dairy farmers surveyed were more cost efficient than the average farmer in the sample. Across types, all type 1 farmers were below the mean efficiency level, whereas more type 2 farmers than type 3 farmers were more efficient than the average dairy farmer in the sample.

(insert table 11 here)

These results indicate that given their current levels of resources and the prevailing prices, dairy farms feeding their cows purely with commercially produced feed concentrates are more cost efficient than those using either a combination of commercial and homemade feed concentrates or purely homemade feed concentrates. Their being more cost efficient relative to the others can be traced to their smaller herd size that did not require more labor hours beyond what the family members can handle. With relatively larger herd size, the other farms would need to invest in more capital intensive equipment like milking machines while at the same time hire additional labor hours needed for production of homemade feed concentrate, e.g. for planting cassava, cutting, drying, and mixing with other feed ingredients. With labor migration to urban areas a common phenomenon in the northeast of Thailand and elsewhere, this need for labor hours is becoming increasingly difficult to be met by available family labor, while competition from other sectors drive wages up. This puts added cost burden to the relatively larger farms, i.e., those with at least 10 head of milking cows, more than the relatively smaller ones, i.e., those with 1-5 head of milking cows.

Taking the empirical estimates further, if dairy farmers in Thailand are able to reduce cost by 26 percent, on average, this will enable Thai raw milk to be competitive in the world market. Average (weighted) raw milk price obtained by smallholder dairy farmers in the survey is US$0.26 per kg of raw milk, which is within the range of average world milk prices. Raw milk prices from the FAO dataset for Australia, China, India, and New Zealand as of 2002 range from a high of US$0.29 cents per kg of fresh cow's milk (China) to a low of US$0.16 cents per kg of fresh cow's milk in Australia (FAO 2004).

Given current productivity levels and with limited changes in current farm practices, this may be feasible albeit difficult to achieve within the near term. Achieving this would require innovations in technology and policy, particularly for feed or sectors linked with the feed industry, as feed cost comprises the largest cost share in dairy production.

Determinants of inefficiency

The variables that were hypothesized to affect the cost inefficiency of dairy farms include a binary variable for the type of feed user, ratio of males to females, age, milking cows to herd size ratio, milk yield, feed concentrate to roughage ratio, percentage of homemade concentrate to total feed consumed, land to labor ratio, and dummy variables for the provinces included in the study. The descriptive statistics of the determinants of cost inefficiency are also shown in table 9.

Results of the estimation of the determinants of cost inefficiency are shown in table 12. Age as a proxy for the dairy farmer's experience was shown to have a significant effect on the cost efficiency of dairy farms. In this case, age was shown to be inefficiency reducing, implying that more experienced farmers are less cost-inefficient than their younger counterparts. Technical factors that significantly affect cost efficiencies are milking cows to herd size ratio, milk yield per cow, and type of feed used. The first two are shown to be inefficiency reducing and point to the potential of appropriate herd management and productivity enhancing technologies to contribute to cost efficiency. Indeed, cost efficiency increases with higher levels of milking cows-herd size ratio, but declines with herd size (see figure 1). Based on previous studies, the suggested ratio of milking cows is 70-75 percent of the herd (Skunmun and Chantalakhana (1999). The observed relationship between efficiency and herd size suggests that smaller farms (in terms of herd size) in this sample of smallholder dairy farms are more cost efficient than larger ones.

The estimated coefficient for type of feed used (a binary variable) indicates that farms using home-made feed concentrates are less cost efficient relative to those that are using commercial concentrate. This result is curious and contrary to expectations as it does not validate the hypothesis that feed technologies using locally available feed ingredients contribute to more cost efficient feed use. While such technologies have shown promising results from on-station experiments (Wanapat et al. 2000), the empirical findings in this study suggest that such have not been successfully replicated outside the experimental stations. This finding points towards identifying options for bridging this gap in technology validation/dissemination and successful adoption outcomes via appropriate and innovative extension modalities.

(insert table 12 here)

Conclusions and Policy Implications

The cost frontier estimates indicate that some smallholder dairy farmers in Northeast Thailand are cost-inefficient. On average, cost of dairy production is 26 per cent higher than the best practice. But more than half of those farms surveyed are more cost efficient than the average farm in the sample. What is also interesting to note is that these cost efficient farms are the relatively smaller ones among this sample of smallholder dairy farms. The presence of economies of scale in dairy farming in this region was not strongly supported by empirical evidence from this study.

Inefficiency can be addressed via a number of technical options, including better herd management to achieve the optimal milking cow-herd size ratio. On the other hand, the results did not provide strong empirical support for cost-efficiency effects from adoption of cassava-based homemade feed concencentrate, despite the latter's promising results from on-station experiments. While cassava-based home-made feed concentrate technology has been shown to be gaining acceptance among a good number of smallholder dairy farmers in northeast Thailand, the fact that under prevailing conditions many resource-constrained farmers have not been able to use it needs to be given careful attention. The ability to adopt cassava-based home-made feed concentrated by some resource-constrained farmers can be enhanced via institutional arrangements that will allow those land- and labor-constrained farmers to have access to a steady supply of low-cost cassava as feed ingredients. One such option is to develop a linkage between agricultural cooperatives of cassava farmers and dairy cooperatives to ensure a more sustainable supply of cassava-based ingredients with better quality and reasonable price. This and other similar arrangements will need to be further explored.

The future of smallholder dairy farms to remain competitive in the changing landscape of a more liberalized dairy markets will require adjustments both in the way small farms operate and in the policy environment that will provide incentives for these small farms to operate in a more cost-efficient manner. Given current levels of productivity and farmer practices, this may be feasible albeit difficult within the near term. Achieving this would require innovations in technology and policy, particularly for feed or sectors linked with the feed industry, as feed cost comprises the largest cost share in dairy production.

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Table 1. Distribution of sample respondents by survey sites.

Province	Study sites	Population (no.)	Samples (no.)
Nongbualamphoo	Nongbualamphoo Dairy Cooperatives	84	8
Mahasarakham	Kokgor Dairy Farmer Cooperatives and Mahasarakham Dairy Cooperatives	163	15
Khon Kaen	Khon Kaen Dairy Cooperative, Nampong Milk Collection Center, and Kranuan Milk Collection Center	494	49
Udon Thani	Kudjub Milk Collection Center, Sithart Milk Collection Center, Thungphon Milk Collection Center, and Udon Thani Dairy Cooperatives	313	31
Sakon Nakhon	Charoensin Milk Collection Center and Warichaphoom Dairy Cooperatives	108	11
Loei	Loei Dairy Farmer Cooperatives and Muang Loei Agricultural Cooperatives	167	16
Total		1,329	130

Table 2. Distribution of sample respondents by type of feed concentrate used.

Type	Definition	No.	Percentage
1	100% commercial feed concentrate user	20	15.4
2	100% homemade feed concentrate user	39	30.0
3	Mixed commercial/homemade feed concentrate user	71	54.6
All types		130	100.0

Table 3. Types of raw materials used as concentrate feed ingredients.

Item	Type 2		Type 3	
	No.	%	No.	%
Cassava chips	33	84.62	58	81.69
Soybean meal	31	79.49	46	64.79
Fine rice bran	29	74.36	46	64.79
Minerals	31	79.48	37	52.11
Commercial feed	0	0.00	63	88.73
Maize	24	61.54	29	40.85
Rice bran	12	30.77	35	49.30
Salt	14	35.90	16	22.54
Palm meal	11	28.21	11	15.49
Urea	11	28.21	8	11.27
Calcium	7	17.95	8	11.27
Vitamins	4	10.26	5	7.04
Brewery grain	2	5.13	4	5.63
Premix	2	5.13	3	4.23
Cassava leaf	1	2.56	3	4.23
Sulfur	1	2.56	2	2.82
Maize silage	1	2.56	1	1.41
Coconut meal	2	5.13	0	0.00
Cassava powder	0	0.00	2	2.82
Molasses	1	2.56	1	1.41
Leucaena leaf	2	5.13	0	0.00
Kapok meal	1	2.56	0	0.00
Mungbean meal	0	0.00	1	1.41
Lime	1	2.56	0	0.00

Source of data: ILRI-KKU survey of smallholder dairy farmers in NE Thailand, 2004.

Table 4. Price per kg of raw materials used as concentrate feed ingredients (Baht per kg).

Item	Type 1	Type 2	Type 3
Cassava chips	–	3.5	3.6
Soybean meal	–	14.7	15.3
Fine rice bran	–	4.8	4.7
Rice bran	–	3.3	3.4
Minerals	–	11.4	15.0
Commercial feed concentrate	6.4	6.5	6.9
Maize	7.5	7.6	7.3

Note: Exchange rate: US$1 = Baht 40.

Source of data: ILRI-KKU survey of smallholder dairy farmers in NE Thailand, 2004.

Table 5. Socioeconomic characteristics of sample respondents.

Characteristic	Type 1 (n = 20)		Type 2 (n = 39)		Type 3 (n = 71)	
	No.	%	No.	%	No.	%
Age of respondents						
16–30	0	0.0	2	5.1	15	21.1
31-45	11	55.0	18	46.2	36	50.7
46-60	8	40.0	19	48.7	18	25.4
More than 60	1	5.0	0	0.0	2	2.8
Average (years)	46.5		44.0		40.0	
Position in the household						
Head	16	80.0	26	66.7	43	60.6
Wife	3	15.0	8	20.5	8	11.3
Other (son, daughter, etc.)	1	5.0	3	7.7	10	14.1
Civil status						
Married	20	100.0	39	100.0	65	91.5
Single	0	0.0	0	0.0	5	7.0
Divorced	0	0.0	0	0.0	1	1.4
Average number of household members						
Male	2.30	56.1	2.41	50.3	2.45	49.4
Female	1.80	43.9	2.38	49.7	2.51	50.6
Total	4.10	100.0	4.79	100.0	4.96	100.0
Average number of available household labor on farm						
Male	0.85	39.5	1.05	42.7	1.08	40.6
Female	1.30	60.5	1.41	57.3	1.58	59.4
Total	2.15	100.0	2.46	100.0	2.66	100.0
Main occupation						
Dairy farmer	20	100.0	34	87.2	63	88.7
Rice farmer	0	0.0	3	7.7	6	8.5
Government official	0	0.0	2	5.1	2	2.8
Secondary occupation						
Dairy farmer	0	0.0	4	10.3	6	8.5
Rice farmer	11	55.0	19	48.7	51	71.8
Other crop production	3	15.0	3	7.7	1	1.4
Merchant	1	5.0	1	2.6	1	1.4
Private officer	0	0.0	1	2.6	0	0.0
No response	5	25.0	11	28.2	12	16.9
Source of household income (%)						
Dairy farming	85.0		79.0		84.9	
Other farm activities	4.0		6.0		6.3	
Nonfarm activities	11.0		14.9		8.8	
Total	100.0		100.0		100.0	
Average total household income (baht)	264,976		558,991		381,068	

Note: Exchange rate: US$1 = Baht 40

Source of data: ILRI-KKU survey of smallholder dairy farmers in NE Thailand, 2004.

Table 6. Profile of smallholder dairy farms surveyed.

Characteristics	Type 1 (n = 20)	Type 2 (n = 39)	Type 3 (n = 71)	All types (n = 130)
Average area per farm (ha)				
Owned	25.49	30.97	23.56	26.08
Rented	0.98	4.28	2.75	2.93
For free	1.68	3.23	4.38	3.62
Total	28.15	38.48	30.69	32.63
Average value of assets per farm (baht)				
Vehicles	43,366	165,517	90,542	98,195
Milk pump machine and milk tank	8,376	25,541	12,549	15,120
Grass-cutting machine	3,096	3,465	3,489	3,434
Water pump	1,407	1,854	814	1,220
Feed mixer machine	0	315.39[a]	0.28[b]	38.46[c]
Electrical generator	0	27.69[d]	0.85[e]	6.46[f]
Total	56,244	196,720	107,395	118,013
Average animal inventory per farm (head)				
Milking cows	5.60	9.49	7.49	7.80
Dry cows	1.25	2.72	2.07	2.14
Heifers (pregnant)	0.75	2.56	1.77	1.85
Heifers (age>2 years, not pregnant)	1.10	1.95	1.11	1.36
Young cattle (age 1–2 years)	2.35	2.95	2.92	2.84
Calves (age 1 month to 1 y)	1.45	2.67	2.56	2.42
Total	12.50	22.34	17.92	18.41
Average distance of farm from feed sources	9.7	9.5	10.7	9.86

[a]Only 4 farmers indicated having this item, average value based on 4 observations is 30,750 baht. [b]Only 1 farmer indicated having this item, value at 2,000 baht. [c]Only 5 farmers indicated having this item, average value based on 5 observations is 25,000 baht. [d]Only 1 farmer indicated having this item, value at 36,000 baht. [e]Only 1 farmer indicated having this item, value at 6,000 baht. [f]Only 2 farmers indicated having this item, average value based on 2 observations is 21,000 baht.

Exchange rate: US$1 = Baht 40

Source of data: ILRI-KKU survey of smallholder dairy farmers in NE Thailand, 2004.

Table 7. Average costs and returns of milk production per farm per year and by type of feed use.

Item	Type of feed concentrate used			All types
	Type 1	Type 2	Type 3	
	%	%	%	%
Cash costs				
Feed concentrate	59	66	61	63
Roughage	9	8	13	11
Interest payment on loans	17	9	8	9
Veterinary supplies	2	2	4	3
Pasture maintenance	1	2	2	2
Hired labor	1	2	1	1
Veterinary services	1	1	2	1
Total cash costs	90	92	91	91
Noncash costs				
Unpaid family labor	8	5	7	6
Interest on operating capital	1	1	1	1
Interest on breeding stocks	1	1	1	1
Depreciation	1	1	1	1
Interest on equipment and buildings	0	0	0	0
Total noncash costs	10	8	9	9
Total costs	100	100	100	100
Total returns	245,182	454,719	339,894	359,770
Net farm income	54,635	110,709	78,126	84,287

Exchange rate: US$1 = Baht 40

Source of data: ILRI-KKU survey of smallholder dairy farmers in NE Thailand, 2004.

Table 8. Weighted costs per unit output of milk production and by type of feed use (Bath/kg).

Item	Type of feed concentrate used								
	Milking cows			Nonproductive cows			All types of farms		
	Type 1	Type 2	Type 3	Type 1	Type 2	Type 3	Type 1	Type 2	Type 3
Cash costs									
Feed concentrate	1.647	1.842	1.710	3.294	3.685	3.421	4.941	5.527	5.131
Roughage	0.242	0.223	0.371	0.484	0.445	0.742	0.725	0.668	1.113
Interest payment on loans	0.465	0.245	0.232	0.930	0.489	0.465	1.395	0.734	0.697
Veterinary supplies	0.069	0.068	0.105	0.138	0.135	0.210	0.208	0.203	0.315
Pasture maintenance	0.031	0.067	0.063	0.062	0.133	0.126	0.093	0.200	0.189
Hired labor	0.029	0.067	0.015	0.058	0.134	0.030	0.087	0.202	0.045
Veterinary services	0.033	0.040	0.043	0.067	0.081	0.086	0.100	0.121	0.128
Total cash costs	2.516	2.551	2.540	5.033	5.102	5.080	7.549	7.653	7.620
Noncash costs									
Unpaid family labor	0.214	0.145	0.182	0.429	0.289	0.364	0.643	0.434	0.547
Interest on operating capital	0.019	0.019	0.019	0.038	0.038	0.038	0.057	0.057	0.057
Interest on breeding stocks	0.021	0.022	0.022	0.042	0.044	0.044	0.063	0.065	0.067
Depreciation	0.028	0.033	0.025	0.057	0.066	0.051	0.085	0.099	0.076
Interest on equipment and buildings	0.002	0.003	0.002	0.005	0.006	0.004	0.007	0.009	0.006
Total noncash costs	0.285	0.222	0.251	0.570	0.444	0.502	0.854	0.665	0.753
Total costs	2.801	2.773	2.791	5.602	5.546	5.582	8.404	8.319	8.372

Exchange rate: US$1 = Baht 40

Source of data: ILRI-KKU survey of smallholder dairy farmers in NE Thailand, 2004.

Table 9. Descriptive statistics of the variables used in the model.

Independent variables	Description	Continuous variables		Categorical variables (percentages)
		Mean	Standard deviation	
Cost function				
C_i	Total annual cost per farm per year (in 100,000 baht)	2.75	1.87	
Y_i	Milk production per farm per year (in tons)	32.97	23.91	
P_{Fi}	Average price of feed concentrate per kg	5.78	1.30	
P_{Ri}	Average price of roughage per kg	1.10	0.62	
P_{Li}	Average wage rate per hour	20.51	24.44	
P_{Oi}	Average price of other inputs per kg of milk output	0.53	0.61	
K_i	Capital stock per farm	7,130.46	5,450.37	
Inefficiency estimation				
FT-U	Feed type user, whether or not the farmer uses homemade feed concentrate			1 = 85.62
M-FR	Male to female ratio in the household	1.27	0.87	
AGE	Age of the dairy farmer	42.18	10.41	
MC-HSR	Milking cows to herd size ratio	0.43	0.14	
Y-CY	Milk yield per cow per year	4.22	1.23	
FC-RR	Feed concentrate to forage/roughage ratio	0.64	1.15	
PER-HMC-TF	Percentage of homemade concentrate to total feed consumed	66.97	36.15	
L-LR	Labor to land ratio	49.26	44.58	
PROV1	Whether or not the dairy farmer is in Nongbualamphoo			1 = 6.20
PROV2	Whether or not the dairy farmer is in Mahasarakham			1 = 11.54
PROV3	Whether or not the dairy farmer is in Udon Thani			1 = 23.85
PROV4	Whether or not the dairy farmer is in Sakon Nakhon			1= 8.46
PROV5	Whether or not the dairy farmer is in Loei			1 = 12.31

Table 10. Parameter estimates of the translog cost function.

Independent variables	Parameter estimates	
	Coefficient	t-value[a]
Cost function estimates		
Y_i	0.320	2.91*
P_{Fi}	0.489	3.64*
P_{Ri}	0.161	1.99**
P_{Li}	0.297	2.00**
K_i	0.343	3.95*
Y_i^2	–0.121	–0.52
P_{Fi}^2	0.426	1.01
P_{Ri}^2	0.089	0.75
P_{Li}^2	–0.207	–1.09
K_i^2	–0.503	–2.36**
P_{Fi} x P_{Ri}	–0.856	–2.08**
P_{Fi} x P_{Li}	–0.109	–0.20
P_{Ri} x P_{Li}	0.662	1.25
Y_i x P_{Fi}	0.503	1.67***
Y_i x P_{Ri}	–0.022	–0.17
Y_i x P_{Li}	–0.489	–1.56
Y_i x K_i	0.396	2.24**
K_i x P_{Fi}	–0.458	–1.94***
K_i x P_{Ri}	0.097	0.83
K_i x P_{Li}	0.406	1.63
Constant	0.881	14.05*
Sigma^2	0.119	7.31*
Gamma	0.353	3.35*
Sample size	130	

[a]* = significant at 1% probability level, ** = significant at 5% probability level, *** = significant at 10% probability level.

Table 11. Average cost efficiency estimates and the distribution above and below the mean efficiency estimate by type of feed use.

Item	Type of feed concentrate used			All types of farms
	Type 1 (n = 20)	Type 2 (n = 39)	Type 3 (n = 71)	
Efficiency estimate	1.048	1.254	1.334	1.266
Distribution of efficiency estimate	(number of respondents)			
Below mean	20	29	39	98
	(100%)	*(74%)*	*(55%)*	(68%)
Above mean	0	10	32	42
	(0%)	*(26%)*	*(45%)*	(32%)

Table 12. Parameter estimates of the determinants of cost inefficiency.

Independent variables	Parameter estimates	
	Coefficient	t-value[a]
Inefficiency estimation		
FT-U	0.979	2.87*
M-FR	0.044	0.62
AGE	–0.013	–1.94***
MC-HSR	–1.990	–3.67*
Y-CY	–1.691	–2.39**
FC-RR	0.043	0.95
PER-HMC-TF	–0.001	–0.38
L-LR	0.001	0.96
PROV1	–0.426	–1.16
PROV2	–0.572	–3.48*
PROV3	–0.201	–1.25
PROV4	–0.273	–1.22
PROV5	–0.151	–0.54
Constant	1.293	2.22

[a]* = significant at 1% probability level, ** = significant at 5% probability level, *** = significant at 10% probability level.

Figure 1. Average efficiency estimates of dairy farms by herd size and milking cows to herd size ratio, Thailand, 2004.