Technical Efficiency in Milk Production of the Dual-purpose Cattle System in El Salvador during Dry and Rainy Seasons

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Abstract

The milk production efficiency of the dual-purpose cattle system (DPCS) was recorded in rainy and dry seasons. How the use of inputs and socioeconomic and technical characteristics turn DPCS farmers operate from less efficient in rainy season to more efficient in dry season are discussed here.

Keywords: Dual-purpose cattle system, technical efficiency, El Salvador, rainy and dry season

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Summary

In producing the milk, dual-purpose cattle system (DPCS) farms change operation pattern from seasons, exhibiting an extensive system in rainy season and intensive in dry season. Operation change effect milk supply, oversupply in rainy season and shortage in dry season. Thus, the stochastic production frontier (SPF) model was used to provide the technical efficiency (TE) score and the determinants of TE of the dual-purpose cattle system (DPCS) in rainy and dry seasons in Morazán, El Salvador. For this study, the survey was conducted in a rural village, San Juan de la Cruz, where the highest cattle population is found. All the DPCS farmers in this village were interviewed twice, including the rainy season of 2009 and the dry season in 2010. In rainy season the main variable with positive effect on production was total cows and feed value in the dry season. Results from the SPF gave TE score of 65 % for rainy season and 84 % for dry season, on average. Thus, the stochastic model showed that the efficiency of this system could be improved by 35 % and 16 %, respectively, if public policies and managerial decisions create and respond to a secure environment in rural areas.

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Introduction

The dual-purpose cattle system (DPCS) is the main alternative to supply milk demand of tropical countries in Latin America. DPCS uses crossbred animal which both adapt to the tropic endowment and farmer socioeconomic characteristics, permitting the production of milk and meat. In El Salvador, DPCS plays an important role in the dairy industry. In the 2006 Agricultural Census, the country had 59,914 farms, 1.04 million cattle, and an annual raw milk production of 456.2 million liters. DPCS accounts for more than 60 % of the national herd and produces about 79 % of the national raw milk (Camara Agropecuaria y Agroindustrial de El Salvador and Banco Multisectorial de Inversiones 2006). Dairy products (fluid milk, cheese and cream), in El Salvador, are highly consumed. Milk per capita consumption was 81.9 kg in 2006, a 4 % increase from 2002.

Due to dairy products demand increase the Ministry of Agriculture and Husbandry of El Salvador has targeted as a main objective, the upgrade of milk producers' efficiency. To study the farm performance, previous researches have usually used the measurement technical efficiency (TE). TE is defined as the ability of a firm to obtain a maximal output from a given set of input (Coelli et al. 2005). The farm model, the TE determinants and TE score estimation have done either by the one or two steps stochastic production frontier (SPF) (e.g., Cabrera, Solis, and Corral 2009; Ortega, Ward, and Andrew 2007; Brovo-Uretra et al. 2008).

With the exception of Ortega et al (2007), studies estimating DPCS model and TE score of Latin America are inexistence. The author estimated a DPCS farm model for a region where rainy period extend up to 9 months, allowing DPCS farmers to keep the same operation pattern, pasture-based, along the year. However, in regions where the green forage availability is interrupted by lengthier dry months (more than 6 months) DPCS farmers have to search for feed stuff alternatives, thus altering the pasture-based operation. The feed stuff change cause, for small farms, a lower milk production, which is reflected in Central America dairy industry, as milk seasonality. There is an oversupply in the rainy season and a shortage in dry season. In addition, a recent study found that lengthier dry months resulted in lower net milk income by very small, small and medium farms (very small size: 1 to 9 cows; small size: 10 to 19 cows; medium size: 20 to 49 cows) in Honduras (Lentes, Peters, and Holmann 2010). Therefore, to represent the best DPCS operation system, the model and TE estimation was done for dry and rainy seasons. Deriving a farm model, TE determinants and TE score for each season might reveal a more accurate estimation of the DPCS system operation.

The objectives of the present study were to estimate the TE of the DPCS farms in the rainy and dry seasons of El Salvador and to identify the determinants of TE of the DPCS in both seasons. We used the econometric approach stochastic frontier (SPF) model to determine the DPCS TE and its determinants. For this study, the survey was conducted in a rural village, San Juan de la Cruz, where the highest cattle population is found. All the DPCS farmers in this village were interviewed twice, including the rainy season of 2009 and the dry season in 2010. Studying farm efficiency and its potential sources of inefficiency are important from a practical and policy point of view (Cabrera, Solis, and Corral 2009).

Methodology

To determine the technical efficiency score and its determinants, we used the stochastic production frontier and the methodology framework given by Coelli and Battese (1995). The empirical analysis estimated using the Cobb-Douglas production function in which both the output and inputs are expressed in logarithmic form. The general representation of the model is as follows:

1) $ln y_i = ln f(x_i, \beta) + v_i - u_i$

Where *y* represents output, *x* is a vector of inputs, *β* is a vector of unknown parameters, *v* is the random error and *u* is the one side error term. The subscripts *í* denote the farm.

To estimate the determinants of TE, we implemented the specification given by Battese and Coelly (1995). We estimated the parameters of the production frontier and the determinants of TE in one step using the Frontier 4.1.

Output and input used

DPCS's operation pattern changes from seasons. For the rainy season (May-October), DPCS farms are pasture-based operators, and for the dry season (November-April), they usually depend on stored forage (silage and crop residues). Thus to represent the best system operation, we decomposed the analysis in both seasons, deriving two set of inputs and socioeconomic variables.

DPCS farm outputs are milk and live cattle (weaned calve). Previous studies have usually set for milk output, since it constitutes the main and daily income for DPCS farmers (Lentes, Peters, and Holmann 2010; Yamamoto, Dewi, and Ibrahim 2007). In the model the dependent variable was the farm milk (or milk products) production sold within six months (in US$). Milk production sold variable has similarly been implemented by previous studies (Cabrera, Solis, and Corral 2009; Ortega, Ward, and Andrew 2007). Setting farm milk sold as the dependent variable allowed us to account for milk destination commonly used by DPCS farmers. Based on data accessed, the model included three inputs for the rainy season: total cows, labor (family and hired), and farm land; and total cows, labor (family and hired), forage and concentrate feed for the dry season (Table 1). The farm land input was excluded from dry season, because grass cannot be grown and little forage can be obtained.

Socioeconomic variables

The socioeconomic and the technical variables used for both seasons were daily milk production per cow-day, family labor (ratio), age, years of education, and a set of dummy variables accounting for milk destination, milk sell, milk processing and sell out of the village (either raw milk or processed product). Some DPCS farmers' sold raw milk to the local artisan and some transformed the milk to cheese, butter and cottage cheese and marketed to the major nearby city (San Miguel). Therefore, the three dummy variables were added to account for milk destination. The specific variables accounting for rainy season improved pasture (measured in hectare) and a dummy variable herd size (≥20 total cows), and the dummy variable forage type (silage or straw) for the dry period.

Table 1. Descriptive statistics of the dual-purpose cattle system farms of El Salvador, San Juan de la Cruz.

Item	Freq.	Mean	SD	Min	Max
Rainy season (N=26)					
Daily milk (L)		45.3	37.9	7.5	157.5
Cows in lactation (n)		9.3	6.9	2	30.0
Total cows (n)		21.6	15.8	4	64.0
Milk/cow/day (L)		4.9	1.9	2.9	11
Family labor		.5	0.4	0	1.5
Hired labor		0.25	0.38	0.0	1.0
Land (Ha)		13.4	11.42	2.8	42.5
Improved pasture (Ha)		3.1	4.6	0.0	21.0
Dry season (N=22)					
Daily milk (L)		46.3	42.8	7.7	153.0
Cows in lactation (n)		7.8	6.8	1.0	30.0
Total cows (n)		20.7	17.3	3.0	75.0
Milk/cow/day (L)		6.2	2.3	2.5	10.6
Family labor		0.59	0.43	0	1.0
Hired labor		0.64	0.56	0.0	2.0
Feed value $/month		705.5	542.8	125.6	2136.6
concentrate kg/month		1242.2	1279.9	181.4	5080.2
Socioeconomic variables(N=26)					
Age		57.9	17.4	20.0	86.0
21 - 40	6				
41 - 60	6				
Over 60	14				
Gender					
Male	21				
Female	5				
Family members		3.9	1.8	2.0	8.0
Members engaged in dairy		1.7	0.9	1.0	4.0
Education		4.61	4.21	0.0	12.0
No education	9				
Elementary school	10				
High school	4				
University	3				

Data description

The dual-purpose farms under study comprised the complete population engaged on the activity, 26 farms, from the village San Juan de la Cruz in the Department of Morazán, El Salvador (13º 35 53’ N latitude and 88º 07’ 35 W longitude). The village is located in the region with the highest cattle population of the country. We used face to face interviews for data collection. The first interview was carried out from July to August 2009, in rainy season; the second in April 2010, during the dry season. In the first interview (rainy season) 26 farmers were milking cows, for the second (dry season), 4 of them were not milking; thus, the total number of DPCS farms for rainy seasons were 26 and 22 for dry season. Over all, the DPCS farmers from San Juan de la Cruz produce milk using the same management practices.

Results and Discussion

Frontier estimates

The model in rainy season included 26 DPCS farms and 22 for dry seasons. Four farmers were not milking in dry season. These farmers were the least efficient in rainy season; on average, they used 7.2 total cows and 5.8 Ha of farm land to produce 12.7 L of milk per day. Table 2 contains the maximum likelihood parameter estimates of the estimated frontier model in the rainy and dry seasons. Since all inputs were measured in logarithmic form, the estimated coefficient values represent the partial output elasticity. In rainy season, the total cows variable was statistically significant with an elasticity effect on productivity level of 0.95. In other words, 1 % increase in total cows implies an estimated increase of farm milk sold of 0.95 %.

In dry season, all the three inputs, total cows, labor and farm land, were statistically significant and had positive sign effect on output with the exception of total cows which had negative sign. Of the three input variables, feed had the highest effect on the output level with an elasticity of 0.55. The second highest elasticity was labor (0.39) and the third on total cows (0.27).

DPCS technical efficiency value

The TE scores for both seasons, rainy and dry, are shown in Table 3. The average TE was 65 % and 85 %, respectively. That is, an average farm could increase its level of milk production by 35 % and 15 % using the current amount of inputs.

A greater TE score (TE > 80 %) in rainy season was linked with an extensive operation system, including the increase of farm land and number of cows. On average, the seven most efficient DPCS farmers used 38 total cows, 1 labor and 24 Ha farm land to produce 97 L of milk per day (range 52.5 to 157.5 L). In addition, four of these DPCS farmers were selling either raw milk or processed products outside the village. On the other hand, the eight least efficient farms (TE < 60 %) used on average 11.8 total cows, 0.6 labor and 7.8 Ha farm land to produce 13.8 L of milk (range 7.5 to 23 L). The eight farms were selling raw milk to the local milk processors (artisans).

Differently, a higher average TE in dry season was achieved due to certain degree of intensification. Four DPCS farmers turned efficient (TE = 100 %) in dry season; it was associated to the use of a less total cows input (-0.267), a more labor and forage (0.392 and 0.550). The four efficient farms (TE = 1) used on average 32 cows, 1.4 labors and US$1081.6 monthly feed value to produce 82.4 L of milk per day (range 15.4 to 153 L). Milk production per cow-day was 7 L. On average, the four least efficient farms (TE < 69 %) used 16.5 total cows, 1.1 labors, $461 monthly feed value to produce 24.2 L (range 13.5 to 46.2 L). Milk production per cow-day was 2.4 L lower than the efficient farms.

Table 2. Production frontier estimates.

	Rainy season		Dry season	
Variable	N=26		N=22	
Frontier	Coefficient	SE	Coefficient	SE
Constant	-0.451***	0.146	-0.346	0.408
Total cows	0.947**	0.426	-0.267**	0.146
Labor	0.829	0.729	0.392**	0.218
Farm land (Ha)/forage ($)[1]	0.111	0.351	0.550**	0.313
Inefficient model				
Constant	0.128	0.462	0.935*	0.558
Improved pasture (Ha)	-0.187	0.936		
Silage			0.434*	0.280
Straw			0.495*	0.330
Milk/cow/day (L)	-0.982**	0.521	-0.183	0.394
Farm size (cows)	0.158	0.677		
Family labor ratio	0.348***	0.119	-0.962***	0.138
Age	0.623***	0.232	0.706***	0.232
Education (years)	-0.721	0.602	-0.187	0.833
Selling milk	0.355**	0.146	0.720*	0.509
Processing milk	-0.227**	0.102	0.206*	0.149
Selling out	-0.282**	0.129	-0.457***	0.112
σ^2	0.417***	0.100	0.314	0.994
γ	0.674***	0.104	0.773***	0.286
Log likelihood	-0.233		-0.192	

*10% level of significance; **5% level of significance; ***1% level of significance

[1] Farm land account for rainy season and forage for dry season

Table 3. Technical efficiency (TE) in rainy and dry seasons.

TE interval %	Farm (n) Rainy season	Farm (n) Dry season
0-49	7	2
50-59	1	
60-69	6	2
70-79	5	2
80-89	4	2
90-100	3	14
average	65%	84%

The use of abundant and low cost grasses in the rainy period (May-October) permits DPCS farms raise milk by increasing the number of cows in lactation. This supports what has traditionally characterized the DPCS as extensive system. Outputs per cow or per unit of land are lower under extensive cattle system (Nicholson, Blake, and Lee 1995); the average TE was, compared to rainy season, 19 % lower. However, milk production cost under this system is very low.

Determinant of technical efficiency

Due to the inverse relationship between technical inefficiency (TI) and TE, the interpretation of the estimated parameters is performed with respect to their effect on TE. Thus, a negative effect on TI has a positive effect on TE. The results of the TI model are presented at the end of Table 2.

Five of the nine socioeconomic and technical variables were negative correlated to TI in the rainy season and four in the dry season. However, three variables were statistically significant ($p < .5$) in the rainy period and three in the dry season.

Milk production per cow-day was the most important factor affecting TE. The result agrees with some previous studies that states efficiency gain could be achieved if producers use animals with higher production level while still using breeds that adapt to tropical environment (Ortega, Ward, and Andrew 2007).

Age variable was negative correlated to the dependent variable and is the second major factor affecting TE in both seasons. However, in dry season, farmers with the TE highest score had an average age of 59.9 years, and the least efficient ones had 36.9 years. Here, which sometimes represent a critical time, older farmers might have more experience on farm management than younger. For instance, Ortega et al., (2007) found that farmers with more than five years of experience were 14 % more efficient than those with less than five years of experience.

Higher proportion of family labor was the third highest factor having a positive relationship with TE in the dry season. This is consistent with the results found in a similar study of the dairy farm in the United States (Cabrera, Solis, and Corral 2009). For rainy season, family labor ratio was negatively correlated to the production. DPCS operation is less labor demanded in rainy season than dry season. But, family labor remains fix and is underused during the rainy season.

Producer’s years of education had a positive effect on production, although statistically insignificant. This result is the contrary documented by Ortega et al. (2007) who found a negative relationship with TE. But, he also found insignificant effect.

The set of dummy variables accounting for milk destination were all statistically significant. It indicates that farmers selling raw milk to local artisans in the village seemed to be least efficient. On the other hand, farmers who were selling in the city usually had a higher production among the group and processed the milk, except two farmers who sold raw milk. The six DPCS farmers selling in the city had average daily milk production of 66.1 L in rainy season and 60.3 L for dry season. This recommends that selling in the city lead to greater farm milk sold.

Both silage and straw dummy variables measuring feed stuff in dry season were statistically significant with negative effect on the dependent variable. We found DPCS farmers were combining both forages, rather than using only one. Thus, we were unable to measure the effect of each variable alone.

The empirical results showed the improved pasture variable, accounting for rainy season, was positive sign effect on production, although statistically insignificant. Some studies argue that pasture system result in lower milk yield (e.g.,Cabrera, Solis, and Corral 2009). DPCS has been shaped by the tropic endowment. Pasture-based operation has been developed.

However, some studies contend that if well managed pasture system can be competitive with highly specialized farms (Nehring et al. 2009). Therefore, the implementation of improved pasture is a technology opportunity that can be adopted by small-scale farmers in the tropic of Latin America (White et al. 1999).

Conclusions

The objectives of the study were to estimate the production frontier, determine the level of technical efficiency score, and define the main factors affecting the technical efficiency, practices commonly used by dual-purpose cattle system in the rainy and dry periods of the village, San Juan de la Cruz, El Salvador.

The empirical results showed that, in rainy season, the total cows input had positive high effect on farm milk sold. The other two inputs, labor and farm land, had positive sign effect, although statistically insignificant. On the other hand, in the dry season the three inputs total cows, labor and feed value were significant correlated with the dependent variable and positive sign effect, with the exception of total cows input which had negative sign effect.

The TE estimation for each season proves DPCS farmers ability to upgrade milk production efficiency by changing operation in the dry season. TE was on average 65 and 84 % for the rainy and dry seasons, respectively. Thus, the stochastic model showed that the efficiency of this system could be improved by 35 and 16 %, respectively, if public policies and managerial decisions create and respond to a secure environment in rural areas.

DPCS farms are pasture-based system in rainy season. The improved pasture variable, although statistically insignificant had positive relationship with TE. Therefore, the implementation of improved pasture is a technology opportunity that can be adopted by small-scale farmers in the tropic of Latin America (White et al. 1999).

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