ECONOMIC DISCUSSION PAPERS

Efficiency Series Paper 04/2007

Does Intensification Help to Improve the Economic Efficiency of Dairy Farms?

Antonio Álvarez, Julio del Corral, Daniel Solís y José Antonio Pérez

Departamento de Economía

Universidad de Oviedo

Available online at: www.uniovi.es/economia/edp.htm

UNIVERSIDAD DE OVIEDO

DEPARTAMENTO DE ECONOMÍA

PERMANENT SEMINAR ON EFFICIENCY AND PRODUCTIVITY

DOES INTENSIFICATION HELP TO IMPROVE THE ECONOMIC EFFICIENCY OF DAIRY FARMS?

Antonio Alvarez[♣], Julio del Corral[♠], Daniel Solís[♥] and José Antonio Pérez[♦]

Efficiency Series Paper 04/2007

Abstract: During recent decades the dairy sector has shown a global tendency towards intensification. This structural change may have significant effects on farm efficiency. The goal of this study is to offer an empirical analysis of the effect of intensification on dairy farming. To do this, we first classify our sample of dairy farms according to their level of intensification using a cluster analysis. We then estimate independent stochastic cost frontiers for each group of farms and calculate their levels of efficiency. The methodology used in this article allows for the presence of different technologies within the sample, a methodological issue frequently avoided in the empirical literature. The empirical results show that intensive farms are closer to their cost frontier than the extensive ones, suggesting a positive relation between intensification and efficiency.

Key words: cluster analysis, efficiency, intensification, stochastic cost frontier

[♣] Corresponding author. Departamento de Economía, Universidad de Oviedo, Spain.
e-mail: alvarez@uniovi.es

[♠] Departamento de Economía, Universidad de Oviedo, Spain.

[♥] Division of Marine Affairs and Policy - RSMAS, University of Miami, Miami, US.

[♦] Departamento de Contabilidad, Universidad de Oviedo, Spain.

1. Introduction

Farm management agents as well as many researchers have advocated reducing production costs as a key factor to boosting profits on dairy farms. In many cases, the way to reduce costs has been to adopt more extensive production systems. The conventional wisdom has it that low-input systems allow farmers to produce at lower average cost than high-input systems.

However, during recent decades and partly associated with the reduction in the total number of dairy farms in most western countries[1] there has been an increasing trend towards the adoption of more intensive systems. The intensification of production is mainly based on an increase in the number of dairy cows per farm, the acquisition of genetically-improved dairy cattle and the increment of concentrates in the diet (FAO, 2006). These structural changes may have significant effects on the economic results of the farms.[2]

In this paper we analyze the effect of dairy farm intensification on the average cost of production. To do so, we first classify our sample of dairy farms according to their level of intensification using cluster analysis. We then estimate a cost frontier for each group of farms and calculate their level of cost efficiency. The data come from a sample of 224 Spanish dairy farms analyzed over an 8-year period.

The results of the empirical analysis show that intensive farms produce at a lower average cost and they seem to be managed more efficiently than farms under more extensive systems. These results provide valuable information that can be used by farm managers to improve cost efficiency. This issue has became very important as experts in this area predict that recent reforms of the European Union Common Agricultural Policy may cause a reduction in milk prices paid to farmers in Europe (Hennessy et al., 2005). A similar tendency has been reported for the US (Chidmi et al., 2005). In such an environment, improving efficiency is essential for the survival of dairy farms (Tauer, 2001).

---

[1] For instance, since 1990 the number of dairy farms in operation has decreased by approximately 38% in the U.S. (U.S. Census of Agriculture), 38% in the UK, 61% in Germany and 73% in Spain (Eurostat).

[2] The intensification of production in the dairy sector has also raised some concerns about the potential negative environmental impacts that it may bring to rural and urban areas, such as ground water contamination (e.g., Berentsen and Tiessink, 2003).

2. Cost functions

A cost function represents the minimum cost required to achieve a certain output level given the input prices. Based on this definition, stochastic frontier analysis (SFA) offers an analytical framework to estimate cost functions (Aigner et al., 1977). Using this framework a stochastic cost frontier is specified as:

$$C = C^*(w, y, t) \cdot \exp(\varepsilon); \quad \varepsilon = v + u \, ; \qquad u \geq 0 \tag{1}$$

where *C* is cost; *C** is the minimum cost, which is function of *w* (input prices), *y* (output level) and *t* (the state of the technology); and *ε* is a composed error term. The components of *ε* are *v,* which is a random variable reflecting statistical noise, and *u*, which is a non-negative term that captures farm inefficiency. If *u* = 0, the farm is producing on the cost frontier (i.e., at minimum cost), while a positive *u* indicates that farm cost is above minimum cost. The two error components are assumed to be independent of each other.

SFA allows us to measure cost efficiency (CE), which can be defined as the ratio of the minimum feasible cost to observed cost. Hence, the CE index is calculated as:

$$CE = \frac{C^*}{C} = \frac{C(y, w, t) \cdot \exp(v)}{C(y, w, t) \cdot \exp(u + v)} = \exp(-u) \tag{2}$$

The higher CE[3] the closer is the farm respect to its frontier. This framework assumes that all producers use the same technology. However, if the farms in the sample use different technologies, then estimating a single technology for all of them could yield biased estimates of the parameters of the cost frontier and the unobserved differences in technologies might be labeled inappropriately as inefficiency. This issue is extremely important for the dairy sector, which has experienced significant structural changes in recent years in the form of a global tendency towards intensification.

In general, the few dairy studies addressing this issue have used ‘expert-knowledge’ to arbitrarily divide their sample based on some specific characteristics. For instance, Hoch (1962) split his sample of Minnesota dairy farms into two groups based on the location of farms. Bravo-Ureta (1986) classified his sample according to herd breed.

[3] The CE is bounded between 0 and 1.

Tauer (1998) and Katsumata and Tauer (2005) estimated different cost functions for farms using alternative milking systems. Lastly, Newman and Matthews (2006) estimated independent stochastic distance functions for specialized and non-specialized dairy farms.

In this study, we use a cluster algorithm to classify our sample of dairy farms according to their level of intensification. This procedure allows us to split the sample into three groups. By doing so, we are able to estimate separate cost frontiers for farms with different levels of intensification.

3. Data

The data used in the empirical analysis consist of a balanced panel of 224 dairy farms which were enrolled in a Record Keeping Program over an 8-year period from 1999 to 2006 (i.e., 2,152 observations). The farms are located in Asturias, a Northern region in Spain where dairy farming is the main agricultural activity. Table 1 provides a descriptive summary of the main variables used in this study.

Table 1. Descriptive statistics (1999-2006)

Variables (Units)	Average	Coefficient of variation	Minimum	Maximun
Average total cost (€/L)	0.31	0.17	0.17	0.55
Milk (L)	293,492	0.65	28,708	1,301,600
Cows (U)	39	0.51	8	153
Labor (FTE[1])	1.76	0.44	0.26	8.73
Land (ha)	19	0.56	3	82
Feed price (€/kg)	0.23	0.10	0.13	0.34
Herd price (€)	144	0.44	18	1,103
Milk per hectare (L/ha)	16,404	0.46	2,850	56,904
Milk per cow (L/cow)	7,196	0.21	2,585	13,918
Feed per cow (kg/cow)	3,419	0.29	918	8,150
Cows per hectare (U/ha)	2.24	0.36	0.45	5.20

FTE=full time equivalent worker

The total cost includes the following items: cost of purchased feedstuffs (concentrates, forages, etc.); forage production costs (seeds, treatments, machinery, etc.); herd expenses (milking, veterinarian, medication, etc.); other expenses (transportation, farm materials, etc.); and fixed costs (social security, opportunity cost of land and family labor, and amortization of buildings and machinery). The average total cost is calculated by dividing total cost by total milk production. All the monetary values are expressed in 2006 euros (€).

To classify our sample of dairy farms according to their level of intensification we implemented a k-means cluster analysis. Milk per cow, milk per hectare, feed per cow and cows per hectare were used as separation variables. It is important to notice that these variables are measured in ratios to avoid grouping farms based on their size. The cluster analysis identified three distinctive groups that we label as extensive, semi-extensive and intensive dairy farms. The clustering process was performed in such way that the single farm's classification could change over time. Consequently, the three groups of farms contain different number of farms in each year. Table 2 shows the evolution of the relative composition of the groups over the sample period. As we can see, the number of farms classified as intensive increases over the years, while the extensive farms display the opposite tendency.

Table 2. Farm classification according to their level of intensification

Groups	Year								Total
	1999	2000	2001	2002	2003	2004	2005	2006	
Extensive	128	113	93	74	69	66	64	68	675
Semi-extensive	83	88	96	103	108	102	100	93	773
Intensive	13	23	35	47	47	56	60	63	344

Table 3 presents the main descriptive statistics for the three groups of farms created in the cluster analysis. As expected, farms using more intensive production systems produce more milk, own more productive cows, consume more feedstuffs, display a higher stocking rate, and in consequence, produce more milk per hectare than their counterparts. It is worth noticing that average total cost (i.e., cost per liter of milk) decreases with intensification.

Table 3. Group characteristics (averages)

	Extensive	Semi-extensive	Intensive
Average total cost (€/L)	0.33	0.30	0.29
Milk (L)	182,978	311,883	469,015

Cows (U)	29	41	54
Purchased feed (kg)	83,878	151,781	224,019
Labor (FTE[1])	1.47	1.82	2.21
Land (ha)	20	18	17
Feed price (€/kg)	0.23	0.23	0.23
Herd price (€)	123	147	177
Milk per hectare (L/ha)	9,348	17,169	28,533
Milk per cow (L/cow)	6,173	7,459	8,612
Feed per cow (kg/cow)	2,829	3,624	4,118
Cows per hectare (U/ha)	1.54	2.36	3.33
Number of observations	675	773	344

FTE=full time equivalent worker

4. Empirical model

As indicated previously, the empirical analysis is based on the estimation of independent stochastic cost frontiers for three distinctive groups of farms classified according to their level of intensification. To estimate these functions we use the translog functional form to avoid unnecessary *a priori* restrictions on the technologies to be estimated. The dependent variable is the average total cost (ATC) and the independent variables include the total production of milk (y), the price of feedstuffs (w_1) and a herd price (w_2). In addition, a set of time dummy variables (D) has been included to account for factors common to all farms such as technical change or weather variability. Thus, the equation to be estimated can be expressed as:

$$\ln ATC_{it} = \beta_0\big|_j + \beta_y\big|_j \ln y_{it} + \sum_{h=1}^{2}\beta_{wh}\big|_j \ln w_{hit} + \frac{1}{2}\beta_{yy}\big|_j \ln y_{it}^2 + \frac{1}{2}\sum_{h=1}^{2}\beta_{whwh}\big|_j \ln w_{hit}^2 + \\ + \sum_{h=1}^{2}\beta_{why}\big|_j \ln w_{hit} \ln y_{it} + \sum_{\tau=2000}^{2006}\delta_\tau\big|_j D_\tau + v_{it}\big|_j + u_i\big|_j \quad (3)$$

where v is a symmetric error term assumed to follow a normal distribution and u is a time invariant non-negative error component assumed to follow a truncated normal distribution. The subscript i denotes farm, t indicates time and j represents the different groups. The vertical bar indicates that the estimation yields parameter estimates for each of the segmented groups.

5. Results and discussion

Table 4 presents the estimated cost frontiers for the extensive, semi-extensive and intensive groups of farms. STATA 9.0 was used in all the estimations. Following common practice, all the explanatory variables in the cost frontiers have been normalized by their geometric mean so that the first order coefficients can be interpreted as cost elasticities evaluated at their respective group geometric means.

The empirical results show the existence of economies of scale at the geometric mean for all three groups. In addition, the parameter μ is significantly smaller for the intensive farms than for the other two groups, indicating that farms using intensive production systems have higher levels of efficiency.

Table 4. Cost function frontiers estimates

	Extensive	Semi-extensive	Intensive
Constant	-1.462***	-1.587***	-1.491***
MILK	-0.147***	-0.102***	-0.024
FEEDPR	0.058	0.082	0.154*
HERDPR	0.046***	0.082***	0.106***
MILK*MILK	0.125***	0.095**	0.107
FEEDPR*FEEDPR	-0.436	0.665	-0.400
HERDPR* HERDPR	0.049	0.107***	0.101*
MILK*FEEDPR	-0.194**	-0.259***	-0.286*
MILK* HERDPR	0.037	0.055*	-0.009
FEEDPR * HERDPR	-0.377***	-0.043	0.190
D2000	-0.014	-0.023	0.011
D2001	0.000	-0.014	0.017
D2002	-0.028	-0.040***	-0.003
D2003	-0.001	-0.011	-0.002
D2004	0.010	0.010	-0.018
D2005	-0.149***	-0.112***	-0.087**
D2006	-0.158***	-0.115***	-0.088**
μ	0.353	0.383	0.251
σ_u^2	0.013	0.009	0.006
σ_v^2	0.012	0.008	0.008
Log. Likelihood	425	618	279

*P < 0.10; **P < 0.05; ***P < 0.01.

To better describe the impact of intensification on production cost and farm efficiency the rest of this section focuses on the results obtained for the extreme groups (i.e., extensive and intensive farms). Figure 1 depicts the cost curves (frontiers) for the year 2006 using the estimates presented in Table 4. The differences between the two curves reflect disparities across the groups in terms of both technology and prices. As we can see, the frontier for the intensive group is always above the frontier for the extensive farms. The minimum average total costs are 0.181 €/L and 0.206 €/L for the extensive and intensive groups, respectively. These optimums are achieved at 508,536 L (extensive) and 532,192 L (intensive).

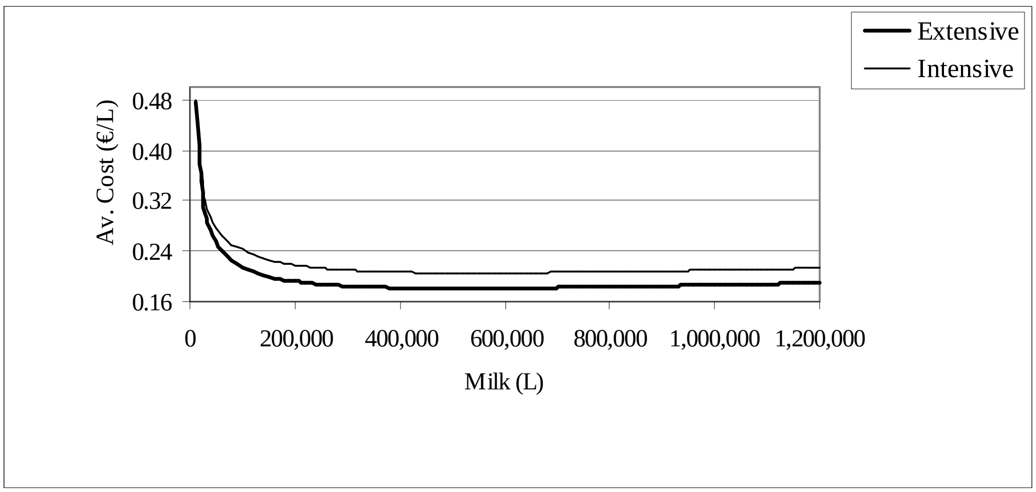

Figure 1. Cost functions (year 2006)

This figure seems to be at odds with the fact that intensive dairy farms, as shown in Table 3, produce at a lower average total cost than extensive farms. The explanation is that, by definition, farms on the frontier curves depicted in Figure 1 must be cost efficient. Therefore, Figure 1 suggests that the higher level of average cost found for the extensive farms can be explained by the presence of inefficiencies. In the rest of this section we will explore this hypothesis.

Table 5 contains the descriptive statistics for the estimated levels of cost efficiency. The results show that the intensive group is more efficient with respect to its frontier than the extensive farms to its frontier. It is important to indicate that this difference is statistically significant based on a paired *t*-test. Furthermore, the coefficient of variation is lower for intensive farms, showing that their efficiency levels are less dispersed.

Table 5. Cost efficiency descriptive statistics

Groups	Average	Coefficient of variation	Minimum	Maximum
Extensive	0.76	0.12	0.59	0.96
Intensive	0.83	0.07	0.73	0.95

These results show that intensive farms are more homogeneous and efficient than the extensive farms. Although our analysis does not allow us to formally explain why farms in the intensive system are more efficient than the extensive ones, we venture the possibility that intensive systems present fewer technical challenges than extensive ones. Specifically, extensive farms use pastures to feed the cows; consequently, they perform several additional production activities (e.g., planting, fertilization, harvest, pasture silage, etc.) to those performed by intensive farms, which base feeding mainly on purchased concentrates. These additional production activities increase the probability of making technical mistakes within the farm-plan, which may negatively affect the level of efficiency among extensive dairy farms.

6. Conclusions

The economic analysis and comparison of farms using alternative levels of intensification in production is important in order to assess how intensification affects the final outcome of dairy farms. This study analyzed the differences in production costs associated with the level of intensification among a sample of 224 dairy farms from Northern Spain. In doing so, we used a cluster analysis to split our sample into three groups according to the level of intensification -extensive, semi-extensive and intensive. We then estimated independent stochastic cost frontiers for each of these groups and calculated their respective levels of efficiency.

Our analysis delivers some interesting conclusions. First, our results show that intensive farms produce at a lower average total cost than extensive farms. In addition, farms in the intensive production system presented higher levels of efficiency than the extensive farms, indicating that the former group is closer to its production frontier than the latter to its frontier. Lastly, the extensive group had the highest level of dispersion of their efficiency indexes. In sum, these results support the idea that farms under intensive production systems are easier to manage than those under extensive systems and consequently that there is a positive relationship between intensification and efficiency.

Our paper aims to contribute to the debate about the advantages and disadvantages of intensive systems. It must be stressed that our results cannot be interpreted *per se* as a support for high-input systems. Many other considerations need to be taken into account in order to decide which productive system is the best. First, environmental issues are especially important and it is widely accepted that pasture-based (i.e., extensive) systems are more environmental friendly. Secondly, cost efficiency depends critically on input prices. In this regard, the recent rise in the price of concentrates due to the increase in the price of cereals may diminish the cost differences between intensive and extensive farms.

References

Aigner, D., K. Lovell, and P. Schmidt. 1977. Formulation and estimation of stochastic frontier production function models. J. of Econometrics 6: 21-37.

Berentsen, P.B., and M. Tiessink. 2003. Potential effects of accumulating environmental policies on Dutch dairy farms. J. of Dairy Science 86: 1019-1028.

Bravo-Ureta, B. 1986. Technical efficiency measures for dairy farms based on a probabilistic frontier function model. Canadian J. of Agricultural Economics 34: 399-415.

Chidmi, B., R.A. Lopez, and R.W. Cotterill. 2005. Retail oligopoly power, dairy compact, and Boston milk prices. Agribusiness 21: 477-491.

FAO (Food and Agriculture Organization). 2006. Livestock report 2006. Rome, Italy.

Hennessy, T., L, Shalloo, and P. Dillon. 2005. The economic implications of complying with a limit on organic nitrogen in a decoupled policy environment - an Irish case. Journal of Farm Management 12: 297-311.

Hoch, I. 1962. Estimation of production function parameters combining time-series and cross-section data. Econometrica 30: 34-53.

Katsumata, K., and L.W. Tauer. 2005. An empirical analysis of Stanchion and Parlor milking cost in New York dairy farms: cost curve and cost function approaches. Department of Applied Economics and Management, Cornell University.

Newman, C., and A. Matthews. 2006. The productivity performance of Irish Dairy farms 1984-2000: a multiple output distance function approach. J. of Productivity Analysis 26:191-205.

Tauer, L. W. 1998. Cost of production for Stanchion versus Parlor milking in New York. J. Dairy Science 81: 567-569.

Tauer, L. W. 2001. Efficiency and competitiveness of the small New York dairy farm. J. of Dairy Science 84: 2573-2576.