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THE IMPACT OF LAND FRAGMENTATION ON MILK PRODUCTION

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ABSTRACT

The effect of land fragmentation on agriculture has worried policy makers for a long time as its effect is expected to be negative. Land consolidation policies are frequently implemented in order to soften the land fragmentation degree. However, there is, to the authors' knowledge, no study in the dairy sector that empirically analyzes the role of land fragmentation on farms' productivity and profits. This study contributes to filling the gap in the literature by evaluating the effect of land fragmentation on milk production. To accomplish this, a stochastic frontier production function has been estimated. This empirical analysis uses information corresponding to a sample of Spanish dairy farms located in a region where dairy production is by far the most important agricultural product and land is highly fragmented. As policy makers in the region assume that land fragmentation has a negative influence on agricultural production and, particularly, in dairy production, a land consolidation process is being developed. Thereafter, a simulation analysis is carried out to evaluate the increase in profits that could be obtained by reducing land fragmentation. The results show that dairy farms could increase their profits in a range between 9.4% and 14% by reducing the land fragmentation degree in a proportion similar to the one attained by the land consolidation process that is being carried out in the region.

Key Words: land fragmentation, technical efficiency, stochastic frontier model

1. INTRODUCTION

Land fragmentation **(LF)**, in which a single farm uses several parcels of land, is a common feature in many countries (Blarel et al., 1992; Wan and Cheng, 2001; van Dijk, 2003). This feature is expected to affect farms' production in a negative way due to several reasons. Some have to do with forage harvesting and are common to other agricultural practices: 1) fragmentation causes an increase in traveling time between fields which induces both lower labor productivity and higher transport costs for inputs and outputs; 2) said practice reduces the efficiency of machines in relation to that obtainable in large, rectangular fields (Buller and Bruning, 1979); and, 3) land is lost when forming plot boundaries and access routes. Other difficulties which are characteristic to dairy production arise if cows are left to graze and are related with the need to move cattle and milking machinery from one plot to another. However, in this study the negative effect of land fragmentation in milk production will be mostly due to reasons common to other agricultural productions, given that only a 15% of the farms in our sample left the cows to graze and the cows are always returned to the stable at the end of the day.

On the other hand, LF is also expected to have some positive aspects for farmers. Differences in elevation and soil type can be exploited by farmers. Crops at lower elevations mature before than those at higher elevations, plots with different soil types permit a farmer to produce a more diversified portfolio of crops; thus differences in elevation and soil type allow harvests to be synchronized with available family labor thus reducing requirements for hired labor. Additionally, LF is expected to reduce production risk associated with the influence of hail storms, floods or fire.

Since the influence of LF on agricultural production can be considered unclear, empirical studies are necessary to assess its effect. Most empirical studies conclude that fragmentation negatively impact agricultural production (Wan and Cheng, 2001; Rahman and Rahman, 2008). However, other studies have not discovered a significant effect of LF on agricultural production (Wu et al., 2005). Therefore, it seems that the effect of LF on agricultural production could depend on the characteristics of the production process analyzed. With regard to the effect of LF on dairy farming, McDowell (1981) indicated that "farm fragmentation is another inhibitor to smallholder participation in dairying. This restricts the practice of grazing and frequently results in low use of crop residues". Hence, LF is assumed to negatively affect milk production. However, there appears to be no study that has analyzed this issue.

Our empirical analysis uses a sample containing management information for 144 dairy farms over a 9-yr period from 1999 to 2007. These farms are located in Asturias, a region in the NW of Spain, where dairy farming is the most important agricultural production. In 2007 milk production was responsible for 50% of agricultural production in Asturias (SADEI, 2009). It is also important to note that land is highly fragmented in the region. The last Agrarian Census conducted in 1999 show that the average number of plots per farm is 12.5 (INE, 2010).

Land parcels combination to ameliorate land fragmentation problems is difficult for dairy farmers due to several factors. The first difficulty is associated with the necessary negotiation among a large number of farmers to interchange plots among each other. Secondly, any change in plot property or boundaries implies legal costs associated to changes in the Registry of the Property which are very expensive in Spain. Finally, access routes are public property in Spain and cannot be changed by private citizens, said prohibition seriously limits the potential for land consolidation.

However, as policy makers assume that LF negatively affects agricultural production; two land consolidation mechanisms have been developed in the region. On the one hand, the Edict 80/1997 (Boletín Oficial del Principado de Asturias, 1997) establishes the conditions under which farmers can request that the public administration develop a land consolidation process. Thus, the administration decides reorganization of the land and this process avoids negotiations and legal costs and also allows the administration to change access routes to the new parcels. On the other hand, the administration itself can promote a local land consolidation process by communicating to the affected farmers that their parcels will be reorganized according to the principles established in the Law 4/1989, Agrarian Regulation and Rural Development (Boletín Oficial Del Principado de Asturias, 1989). Land processes using both procedures affected 6,722 farms during the 1998-2007 period. Specifically, 17,545 ha divided into 50,152 plots were concentrated into 13,949 plots (SADEI, 2009).

The empirical effect of LF on agricultural production has been frequently analyzed by estimating production functions. Some studies have included a LF measure as an additional input in the production function estimation (Wan and Cheng, 2001; Wu et al., 2005). Other studies have analyzed the effect of LF on agriculture using the stochastic production frontier (**SPF**) approach including some measure of LF as a determinant of the inefficiency component (i.e., the ratio between the actual production and the one attained by fully exploiting the technological potential). Specifically, Wadud and White (2000) and Rahman and Rahman (2008) analyzed the influence of LF on technical efficiency **(TE)** for rice farmers in Bangladesh. Carter and Estrin (2001) included a measure of LF in order to analyze the efficiency determinants in multiple crop farms in China. This study follows the latter approach that allows identifying the maximum output technologically attainable and the effect of LF is tested by measuring whether it generates losses in milk production in regard to the maximum potential one. Consequently, the present study implements a SPF model to analyze the impact of LF in

TE among Spanish dairy farms. The results showed that LF negatively affects milk production. To evaluate the impact of a land consolidation process we carried out a simulation. According to this simulation, reducing the number of plots of the average farm from fourteen to four allows for an increase in profits, on average, of 11.7%.

2. MATERIALS AND METHODS

Stochastic Frontier Model

To study the effect of LF on milk production we used a stochastic frontier model (**SFM**) proposed by Aigner et al. (1977). A stochastic frontier production function may be written as:

$$y_{it} = f(x_{it}) \cdot \exp(\varepsilon_{it}); \varepsilon_{it} = v_{it} - u_{it} \quad [1]$$

where subscripts *i* and *t* denote, respectively, farm and time period, *y* represents the output quantity, *x* is a vector of inputs, *f(x)* represents technology, ε is a composed error term. Component *v* captures statistical noise and other stochastic shocks which enter into the definition of the frontier items such as weather, diseases, etc. and it is assumed to follow a normal distribution centered at zero. On the other hand, *u* is a non-negative term that reflects farm technical inefficiency (i.e., the proportion in which actual output can be augmented to reach the maximum technologically feasible one) and which is assumed to follow a truncated-normal distribution.

SFM can be used not only to estimate the frontier production parameters, but also to analyze the determinants of the inefficiency component. Early approaches to this technique estimated a SFM and subsequently the estimated efficiencies were regressed against some exogenous variables in a second-stage regression. However, there are serious econometric problems associated with this two-stage formulation. Wang and Schmidt (2002) demonstrate than if in the first step "the dependence of inefficiency on z is ignored, the estimated firm-level efficiencies are spuriously under-dispersed. As a result the second-step regression understates the effect of z on efficiency levels" (Wang and Schmidt, 2002; p. 130). To avoid these problems several authors developed the so called one-stage models (e.g., Huang and Liu, 1994; Battese and Coelli, 1995; Caudill et al., 1995) in which the inefficiency effects are estimated simultaneously with the technological parameters. To accomplish the objective of analyzing the effect of LF on farm TE the Battese and Coelli (1995) model will be used. This model can be expressed as:

$$y_{it} = f(x_{it}) + v_{it} - u_{it} \qquad u_{it} = z_{it}\delta + W_{it} \qquad [2]$$

where z is a vector of farm-management variables that explain inefficiency, δ is a vector of parameters to be estimated and W is defined by a normal distribution truncated at $-z\delta$ with zero mean and variance σ_u^2. It is also assumed that v and u are independent. This model allows the efficiency distribution to depend on both kinds of variables: time-invariant and time-variant for each firm, which is the case in the study at hand. The parameters of the stochastic frontier and the model for the technical inefficiency effects are simultaneously estimated by maximum likelihood.

The SFM depicted in equation [1] allowed measuring an index for TE, which is defined as the ratio of the observed output (y) and maximum feasible output (y*):

$$\mathrm{TE}_{it} = \frac{y_{it}}{y_{it}*} = \frac{f(x_{it})\cdot\exp(v_{it} - u_{it})}{f(x_{it})\cdot\exp(v_{it})} = \exp(-u_{it}) \qquad [3]$$

Because y is always lower than or equal to y*, the TE index is bounded between 0 and 1. TE achieves its upper bound when a dairy farm is producing the maximum technologically feasible output (i.e., $y = y$*), given the input quantities.

Empirical Model

In this study the production function is modeled using a flexible functional form. This form is based on a second-order Taylor expansion which allows for a good approximation to the true, and unknown, production function (Chambers, 1988). The translog functional form (Christensen et al., 1973) was chosen for this study. This functional form is frequently used to model dairy production (e.g., Alvarez and Arias, 2004; Lawson et al., 2004; Roibas and Alvarez, 2010).

The dependent variable is the production of milk. Five inputs are considered: *labor*, which includes family labor and hired labor and is measured in man-equivalent units, i.e., a full-time adult employee with 1,920 hours per year (40 hours per week for 48 weeks in a year); *cows*, defined as the number of adult cows in the herd; *concentrates*, measured in kg; *forage expenses*, defined as forage purchases plus the costs of seeds, fertilizers, machinery, fuel and land and *animal expenses*, defined as livestock supplies, breeding and veterinary expenses. All the monetary variables are expressed in 2007 Euro (€). Additionally, time dummy variables were introduced to check for factors that affect all farms in the same way, but which may vary over time, such as weather variations and technical change (1999 is the base year).

The variables included as inefficiency determinants were a measure of LF and other variables related with farm practices and characteristics. LF can be measured in several ways; including the Simpson index (Simpson, 1949; used by Blarel et al., 1992 and Wu et al., 2005; among others), the number of plots (Wan and Cheng, 2001; Falco et al., 2010) and the average plot size (Nguyen et al., 1996; Wadud and White, 2000). The use of the Simpson index is not possible given that the data does not contain information about the plots surface (only the farm land surface and number of plots is known). Thus, in this study LF was measured by the *number of plots.* The square of the number of plots is also included because of the expectation that the influence of an additional plot diminishes with the total number of plots (i.e., the influence of an additional plot in milk production is expected to be different for a farm with 2 plots than for a farm with 25 plots).

Other variables included as inefficiency determinants were *concentrates/cow* (Hallam and Machado, 1996; Kompas and Che, 2006; Cabrera et al., 2010); *land*, defined as the total number of ha used on the farm; *family labor* (Cabrera et al., 2010), the ratio of family labor to total labor; *equipment per cow* (Hallam and Machado, 1996), equipment including, machinery amortization plus fuel and electricity expenses; *owned land*, the ratio of owned land to total land, which can be considered as a measure of land dispersion since owned land is expected to be closer to the farm than rented land; *pasture* (Cabrera et al., 2010), a dummy variable equal to 1 for farms that left the cows to graze; *housing* (Cabrera et al., 2010), a dummy variable equal to 1 for farms that use freestall housing; *milking system* (Cabrera et al., 2010) a dummy variable that takes on the value of 1 if the milking system is parlor and 0 if otherwise and to consider different weather and ground conditions a dummy variable, *zone*, which is equal to 1 for farms that are located in a coastal county, is included.

Thus, the model to be estimated can be expressed as:

$$\ln y_{it} = \beta_0 + \sum_{j=1}^{5} \beta_j \ln x_{jit} + \frac{1}{2} \sum_{j=1}^{5} \sum_{k=1}^{5} \beta_{jk} \ln x_{jit} \ln x_{kit} + \sum_{t=2000}^{2007} \beta_t D_t + v_{it} - u_{it} \qquad [4]$$

$$u_{it} \sim TN\left(\delta_0 + \sum_{l=1}^{11} \delta_l z_{lit}, \sigma_u \right) \qquad [5]$$

where subscripts *j* and *k* are used as inputs and subscript *l* is used for the inefficiency explanatory variables. D_t refers to the year dummies. β_0, β_j, β_t, β_{jk}, and δ_l are the parameters to be estimated. $TN(\cdot)$ refers to the truncated normal distribution. Stata 10.0 was used in all the estimates.

Data

The data used in the empirical analysis consists of an unbalanced panel of 144 Spanish dairy farms which were enrolled in a voluntary record-keeping program which is conducted by the regional government over a 9 year period from 1999 to 2007. This record-keeping program collects information about nine Dairy Farmers Management Associations located in Asturias. These associations are funded by the regional government and their main objective is to provide management advisement to its associated farmers. To collect the data necessary for the advisement function, each farm is visited monthly by a technician. The monthly information is combined with annual inventories to carry out an annual report of each farm. Data proceeding from these annual reports have been used in other studies regarding dairy farm production (Roibas and Alvarez, 2010; Alvarez and del Corral, 2010 and Alvarez et al. 2008). Furthermore, in 2008, a survey was conducted among the farmers associated to the Dairy Farmers Management Associations to determine the number of plots that each farm had in 2007.

The analysis has been carried out assuming that while a farm does not change the number of ha then the number of plots remains constant. That is, if for some farm the number of ha in 2004 is different from that on 2007, then observations corresponding to 2004 and previous years are excluded from the data. This is the main reason for the increasing number of observations per year (see Table 1). It is noteworthy to indicate that from what is observed on the database this is not a strong assumption. This selection process leads to an unbalanced panel that contains 1,130 observations.

Table 2 provides a descriptive summary of the variables used in this study. The dairy farms in the sample are highly specialized with more than 90% of farm income coming from dairy sales. The average farm size in the sample is larger than the average Spanish farm (26 cows; Eurostat, 2010) but similar to the average farms in some of the main milk producers countries in Europe like France or Germany (40 cows; Eurostat, 2010). Differences among farms are quite important as the standard deviation of milk production is 67% of the mean production. Finally, it is worth noting that land is highly fragmented since the average number of plots per farm is, roughly, fourteen.

In a preliminary analysis, the farms were classified into two groups depending on if the number of plots is smaller or greater than the sample median (11 plots). Variable profits (milk sales minus feeding costs and animal expenses) per cow were calculated for each farm. Table 3 shows the average variable profits per cow for each group of farms in each sample period. In every year, except 2002, farms using less than 11 plots achieve larger variable profits per cow than farms using more than 11 plots. On average, farms using less than 11 plots earn 50 € more per cow than farms using more than 11 plots. However, this preliminary analysis does not allow us to conclude that the number of plots is the unique cause of the observed economic advantage of the first group. Other differences among the farms can also contribute to these differences in profits. The estimation of the empirical model proposed in equations [4] and [5] will permit the influence of land fragmentation on farms' profits to be isolated.

3. RESULTS AND DISCUSSION

Following a common practice when estimating a translog functional form (Cuesta, 2000; Alvarez et al., 2008; Moreira and Bravo-Ureta, 2010) the explanatory variables were divided by their geometric mean, so that the first order coefficients can be interpreted as output elasticities, i.e., the percentage change in production when the corresponding input increases by 1%, for a farm characterized by an input endowment equal to the sample geometric mean.

Table 4 presents the estimated production frontier and the inefficiency determinants. All output elasticities were positive and statistically significant, that is, all inputs have a positive impact on milk production as is expected. The input with the highest output elasticity was *cows* (0.68). That is, a 1% increase in the number of cows results in an estimated increase of 0.68% in milk produced. The other output elasticities are *labor* (0.06), *concentrates* (0.08), *forage expenses* (0.15), and *animal expenses* (0.08). Time dummies show that during the sample period productivity increases by around a 13-14%. Time dummy coefficients include technical change as well as any other not observed variables which are time specific such as weather. Roibás and Alvarez (2010) use a similar database to show that the main source of technical change is genetic progress. Scale elasticity (i.e., the sum of all output elasticities) is 1.05 which is different from 1 ($P<0.01$) showing some slight increasing returns to scale. That is, if all the inputs increase in the same proportion then the milk production will increase in a slightly larger proportion. This result is in line with previous studies using a similar data set (see Alvarez and del Corral, 2010).

With regard to the focus of this study, the results suggest that technical inefficiency increases with *the number of plots* ($P<0.01$) but this influence is attenuated with the number of plots given that the coefficient of quadratic term is negative ($P<0.01$). Moreover, *concentrates/cow* increases TE ($P<0.01$). The same outcome was also found in Cabrera et al. (2010) for Wisconsin dairy farms, in Hallam and Machado (1996) for Portuguese dairy farms and in Kompas and Che (2006) for Australian dairy farms. This result shows that intensive farms tend to be more efficient than extensive ones (Alvarez and del Corral, 2010). *Land* and *family labor* have a positive coefficient ($P<0.1$) indicating that the more land and the greater the percentage of family labor, the less technically efficient the farm is. Cuesta (2000) found a negative elasticity of labor for Spanish dairy farms and argues: “farms in the sample are family run farms and the labor variable could be reflecting a disguised unemployment problem”. It is clear that this problem is not associated to farms using hired labor, but farms using only family labor can, at least partially, continue suffering from this problem. As was expected, TE increases with the ratio of *owned land* showing that the closer the parcels are to the farm the more technically efficient it is ($P<0.05$). The coefficient of the *zone* variable is positive ($P<0.01$) which means that conditions for dairy farming are better in the interior that in the coast. Freestall farms were found to be more efficient than non-freestall farms. On the other hand, parlor farms were found less efficient than stanchion farms ($P<0.05$). In our sample most freestall farms (over 90%) use a parlor milking system and most of non-freestall farms use a stanchion milking system, however, according to our results, the most efficient farms are freestall farms using a stanchion milking system. Lastly, the variables *equipment/cow* and *pasture* were found non-significant. Related to *pasture* a similar result was found in Cabrera et al. (2010).

In order to evaluate the influence of LF on milk production, a simulation analysis was carried out. The expected TE score is calculated for the average farm, which corresponds to the average values on inputs and efficiency determinants on Table 2 (for efficiency determinants defined as dummy variables we choose the most efficient configuration, i.e. a freestall farm that uses a stanchion milking system and that is placed into the interior zone of Asturias), depending on the number of plots. u_{it} expectation is calculated using the following expression (Stevenson, 1980):

$$E(u) = \delta_0 + \sum_{l=1}^{11} \delta_l z_{it} + \sigma_u \frac{\phi\left(-\left(\delta_0 + \sum_{l=1}^{11} \delta_l z_{it} \right) \Big/ \sigma_u \right)}{1 - \Phi\left(-\left(\delta_0 + \sum_{l=1}^{11} \delta_l z_{it} \right) \Big/ \sigma_u \right)} \qquad [6]$$

where ϕ represents the standard normal density function and Φ is the standard normal distribution function. Figure 1 represents the expected TE score for the average farm for a quantity of plots between 4 and 22 (which roughly correspond to adding and subtracting one standard deviation to the sample average). A proportional reduction in the number of plots similar to that achieved by the land consolidation process carried out in Asturias implies a reduction in the number of plots from 14, which roughly correspond to the sample average, to 4. This reduction in the number of plots implies an increase in the expected TE index for the average farm from 89.6% to 93.3 % (see Bravo-Ureta et al., 2007; for technical efficiency in dairy farming studies).

To evaluate the economic impact of an increase in TE based on a reduction in the number of plots, the "variable profits" attained are simulated for the average farm during the sample period. Variable profits are defined by the difference between the income generated by selling milk and the "variable costs" including animal expenses and feeding costs (forage expenses plus concentrates cost). Income due to milk sales are calculated using the average milk price on the sample for each year. The expected output is calculated by plugging the input endowment corresponding to the average farm on the estimated function. To calculate concentrates cost, the average sample concentrates price by year is used. Table 5 shows yearly milk and concentrates prices expressed in 2007 Euro per liter and 2007 Euro per kilogram, respectively. Therefore, yearly differences in profits are caused by differences in milk and concentrates prices and on yearly productivity differences associated to time dummies. Differences in profits due to number of plots are only associated to changes in TE. Table 6 shows the variable profits simulation.

Table 7 shows the percentage variable profit increase due to a reduction in the number of plots from 14 to 4. Therefore, a reduction in the number of plots similar to the one carried out by the consolidation process in Asturias allows for, on average, an 11.7% increase in profits. The minimum increase (9.4%) corresponds to the more profitable year 2001. On the other hand, the maximum increase takes place in 2006 (14%) which is the least profitable year. Therefore, the proportional impact of LF increases with low values of milk prices. Thus, as milk prices are expected to remain in low values, the relative impact of LF is also expected to be greater in the future.

4. CONCLUSIONS

LF is expected to have both, positive and negative effects on agricultural production. Thus, the net effect of LF on milk production has to be empirically established. This objective is accomplished by using a sample of Spanish dairy farms located in a region where dairy farming is responsible for 50% of the total agricultural production, which is characterized by a high degree of LF and where a land consolidation process is being carried out.

A SPF approach was used to assess the influence of LF on milk production. The results show that LF has, as expected, a significant negative influence on farmers' TE. According to the estimation, reducing the number of plots of the average farm from fourteen to four allows for an increase in profits, on average, of an 11.7%. It is worth noting that the impact of this reduction in the number of plots increases when milk price is low. Thus, the analysis carried out in this study shows that a land consolidation policy could be a useful tool to improve farmers' profitability, especially in a situation where milk prices are expected to remain low in the future.

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Table 1. Number of farms available in each year

1999	2000	2001	2002	2003	2004	2005	2006	2007
106	104	116	122	127	132	136	144	143

Table 2. Descriptive statistics for sample dairy farms over the 1999 to 2007 period

Variable	Mean	CV[1]	Minimum	Maximum
Milk (Liters)	311,346	0.67	31,665	1,202,702
Labor (FTE[2])	1.76	0.45	0.37	8.73
Cows (number of)	40.12	0.51	8.50	149.25
Concentrates (Kg)	149,593	0.73	12,147	789,215
Forage expenses (€)	26,828	0.81	652	176,946
Animal expenses (€)	13,807	0.78	714	148,822
Land (ha)	18.67	0.57	2	82
Plots (number of)	13.55	0.61	2	46
Concentrates/ cow (ratio)	3,488	0.30	994	6,878
Family labor (ratio)[3]	0.95	0.18	0	1
Equipment/cow	268	0.51	17	843
Owned land (ratio)	0.57	0.51	0	1
Zone (dummy)[3]	0.28	1.61	0	1
Pasture (dummy)[4]	0.15	2.39	0	1
Housing (dummy)[5]	0.47	0.93	0	1
Milking system (dummy)[6]	0.48	0.96	0	1

[1] CV= coefficient of variation
[2] FTE= full-time equivalent worker.
[3] Family labor=family labor/total labor
[4] Owned land=own land/total land
[5] Coast=1
[6] Use of pasture=1
[7] Free stall housing=1
[8] Parlor=1

Table 3. Yearly variable profits per cow on farms using less and more than 11 plots (sample median)

	1999	2000	2001	2002	2003	2004	2005	2006	2007
-11 plots	1198[1]	1230	1396	980	1060	1130	1133	917	1122
+11 plots	1129	1143	1365	1038	1025	978	1055	904	1076

[1] 2007 Euro per cow.

Table 4. Production frontier estimates

Variable	Coefficient	SD
Frontier		
Constant	12.546***	0.031
Labor (FTE)	0.056***	0.015
Cows (n)	0.683***	0.045
Concentrates (kg)	0.081**	0.039
Forage expenses (€)	0.146***	0.013
Animal expenses (€)	0.080***	0.011
$Labor^2$	-0.110*	0.060
$Cows^2$	-0.923***	0.177
$Concentrates^2$	0.001	0.078
Forage $expenses^2$	0.023	0.025
Animal $expenses^2$	-0.034	0.030
Labor × cows	0.234***	0.076
Labor × Concentrates	0.005	0.040
Labor × forage expenses	-0.065***	0.025
Labor × animal expenses	-0.046*	0.028
Cows × Concentrates	0.123	0.087
Cows × forage expenses	0.230***	0.053
Cows × animal expenses	0.183***	0.056
Concentrates × forage expenses	-0.153***	0.031
Concentrates × animal expenses	-0.062*	0.034
Forage expenses × animal expenses	0.057***	0.022
T_{2000} (dummy)	0.021	0.016
T_{2001} (dummy)	0.035**	0.016
T_{2002} (dummy)	0.056***	0.016
T_{2003} (dummy)	0.062***	0.016
T_{2004} (dummy)	0.075***	0.016
T_{2005} (dummy)	0.121***	0.017
T_{2006} (dummy)	0.143***	0.018
T_{2007} (dummy)	0.136***	0.018
Inefficiency model		
Constant	0.2946***	0.0839
Plots (n)	0.0130***	0.0026
$Plots^2$	-0.0002***	0.0001
Land (ha)	0.0014**	0.0006
Concentrates/ cow (ratio)	-0.0001***	0.0000
Family labor (ratio)	0.0940*	0.0498
Equipment/cow (ratio)	0.0001	0.0001
Owned land/total land (ratio)	-0.0385**	0.0184
Zone (dummy)	0.0480***	0.0129
Pasture (dummy)	-0.0096	0.0147
Housing (dummy)	-0.0685***	0.0178
Milking system (dummy)	0.0444**	0.0192
σ_u	0.0925	
σ_v	0.0877	
Log-likelihood[2]	825.46	

[1] Coast=1

[2] Use of pasture=1

[3] Free stall housing=1

[4] Parlor=1

*$P < 0.10$; **$P < 0.05$; ***$P < 0.01$

Table 5. Milk and concentrates prices in 2007 Euro

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007
Milk price (Euro/L)	0.48	0.46	0.49	0.42	0.40	0.39	0.36	0.33	0.37
Conc. price (Euro/Kg)	0.34	0.31	0.29	0.29	0.28	0.29	0.28	0.26	0.24

Table 6. Average farm variable profits depending on the number of plots (2007 €)

Plots	1999	2000	2001	2002	2003	2004	2005	2006	2007
4	55,623	56,431	69,040	49,035	46,513	45,228	42,309	36,793	50,903
5	55,062	55,887	68,456	48,526	46,023	44,738	41,835	36,347	50,416
6	54,489	55,331	67,860	48,007	45,524	44,237	41,352	35,893	49,919
7	53,907	54,767	67,256	47,481	45,017	43,730	40,861	35,431	49,415
8	53,321	54,199	66,646	46,950	44,506	43,218	40,367	34,966	48,906
9	52,733	53,630	66,036	46,418	43,994	42,705	39,872	34,501	48,397
10	52,150	53,064	65,429	45,890	43,485	42,196	39,380	34,038	47,891
11	51,574	52,506	64,830	45,369	42,983	41,693	38,894	33,581	47,391
12	51,010	51,960	64,244	44,859	42,492	41,201	38,419	33,134	46,903
13	50,463	51,430	63,675	44,363	42,015	40,724	37,957	32,700	46,428
14	49,937	50,920	63,129	43,887	41,557	40,265	37,514	32,283	45,972

Table 7. Percentage increase in variable profits reducing plots from 14 to 4

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007
% increase	11.4%	10.8%	9.4%	11.7%	11.9%	12.3%	12.8%	14.0%	10.7%

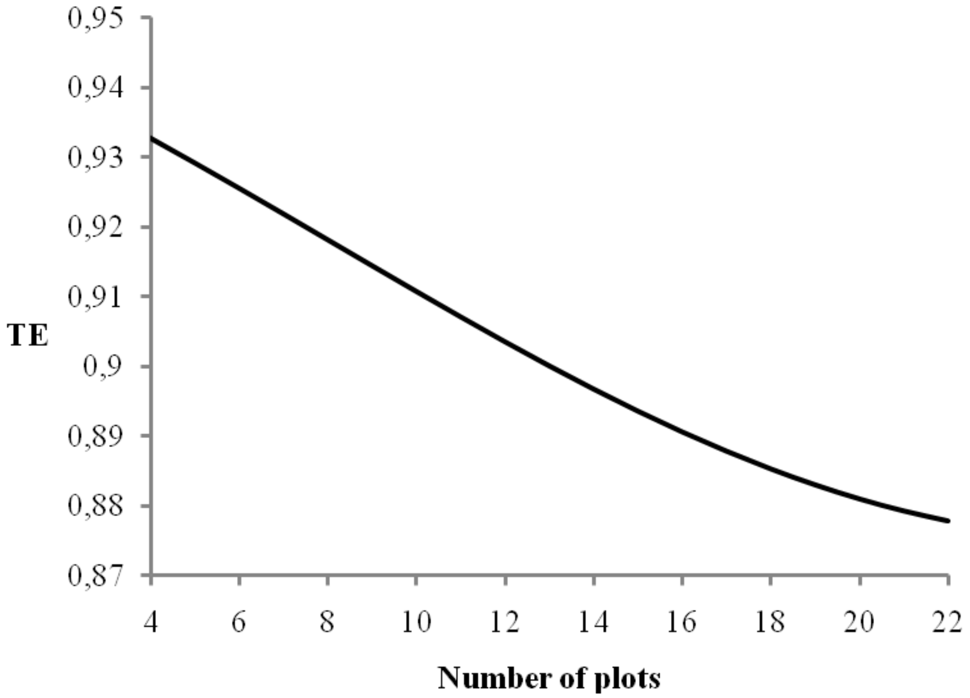

Figure 1. Expected TE for the average farm