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# Technical Efficiency in Portuguese Dairy Farms

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## Abstract

This paper addresses issues related to efficiency measurement from an empirical point of view. A stochastic frontier production model using a translog is estimated for a group of Portuguese dairy farms. Farm level survey data for the period 1988 -2005 is used. Stochastic Frontier estimates address behaviour across all periods so the empirical model allows for time varying efficiency as well as technical change. Previous empirical studies use either the value of production or the quantity of milk produced in a single output framework. The value of production approach bundles together decision regarding the quantity and quality components as well as CAP subsidies. Using both approaches for the same data set produce substantial differences in efficiency measurement. The analysis shows that while farmers are quite efficient maximizing quantity produced they are much less efficient when allowing for quality. Sensitivity of estimates to the heterogeneity of the panel data sample as well as to the specification of the dependent variable is discussed. Average efficiency is 84% which indicates a close proximity to the production frontier for 71% of dairy farms but one can not reject the hypothesis that efficiency is decreasing over time and the rate of technical change is negative and close to 2%.

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## Introduction

Portuguese dairy policy during the 80´s and 90´s was directed towards modernization and increased production trying to fill the gap between quota attributed to the country in 1986 and actual deliveries. In this context questions of productivity and performance of dairy farms were especially relevant. The competitivity of dairy production in the context of Portuguese accession to the European Community has been explored by Langworthy (1987) and Lopes (1989) and Monke (1986) presents the case for Portuguese agriculture in general. The technical efficiency of Portuguese agriculture has been studied for a sample of dairy producers in the Northwest by Hallam and Machado (1996) and a group of dairy farms in the Azores by Silva and Berbel(2002). Recent work include the efficiency of wine producers in Alentejo by Sousa Henriques(2006) and Silva(2006) re-examines milk and beef producing farms using FADN data.

The two main Portuguese dairy producing regions are the Northwest and the Azores which contribute with 35% and 28% of total deliveries respectively. Of the 11106 Portuguese dairy producers 3920 are from the Northwest and 3207 from the Azores. The structure of dairy farms in Portugal and the Azores is summarized in Table 1, using European Size Units (ESU) which allows farm size to be measured in terms of value added to variable inputs. Table 1 shows the average value added in Portugal and in the Azores for small, medium and large sized farms. Small and medium size farms in the Azores have an average value added of approximately 73% of the national average, and large Azorean farms produce only 62% of the national value. The reason for this difference can be attributed either to a smaller productivity or a lower value for the final product. As the price of milk in the Azores is on average 13% lower than the average price for Portugal it explains most of the difference in value added for the small and medium size dairy farms. However for larger dairy farms most of the difference can be attributed to differences in productivity.

When discussing the possible dismantlement of the quota regime the questions of productivity and performance are again relevant to the survival and profitability of small and medium size farms and of regional production. Productivity and efficiency are linked with the level of technical efficiency, price efficiency and scale efficiency. This paper addresses issues related to efficiency measurement from an empirical point of view for a sample of Azorean dairy farms included in the FADN survey. The methodology underlying the present analysis is presented in section 2 and the empirical results presented in section 3. Questions relevant to the empirical measurement of efficiency as well as the structural parameters of the production frontier are discussed in section 4 and the final section summarises the paper and makes some concluding comments.

## 2. Econometric modelling and efficiency measurement

Technology and efficiency measurement can be looked at either from a primal or a dual perspective. A primal approach as originally proposed by Aigner et all. (1977) and Meusen and Van den Broeck(1977) is used to estimate a stochastic production frontier. A single output stochastic production function can be expressed as

$$Y_{it} = f(x_{it}, t, \alpha) e^{(v_{it} - u_{it})}$$

Where Y is the product of farm i in year t, $f(\cdot)$ is the production frontier, x is the vector of inputs, v accounts for random variation in output and measurement errors and assumed to be iid $N(0, \sigma_v^2)$, u is an asymmetric non-negative random error assumed to be $N^+(0, \sigma_u^2)$ and accounts for technical inefficiency in production.

As proposed by Battese and Coelli(1995) the inefficiency effects are modelled as

$$u_{it} = \exp[-\eta(t - T_i)]u_i$$

When $\eta > 0$ the degree of inefficiency is decreasing over time and when $\eta < 0$ the degree of inefficiency is increasing over time.

According to Kumbahkar and Tsionas(2003) when technical inefficiency enters multiplicatively into the production function, as an output-output model, the elasticities of product and returns to scale are independent of the technical efficiency. Output-output technical inefficiency can be interpreted as the percent loss of output, ceteris paribus, due to technical inefficiency.

In the model used as in Battese and Coelli (1995) the effects of technical inefficiency are random variables, non negative and independently distributed. When variables are represented in log form the efficiency of each farm is given by

$$TE_i = \frac{q_i}{\exp(x_i\alpha + v_i)} = \frac{\exp(x_i\alpha + v_i - u_i)}{\exp(x_i\alpha + v_i)} = \exp(-u_i)$$

If $TE_i = \theta <= 1$ then $1-\theta$ is the percentage of output loss or the percent at which the output can be increased without increasing the inputs.

3. Application to Portuguese dairy farms

A panel data (1988-2005) drawn from the FADN data set on Portuguese dairy farms is used. Dairy farms included in the panel are specialist milk producing farms, farm type 41 in the FADN classification. The panel includes a period where quota restrictions where not binding, 1988-1999, and the period where quota effectively affected production decisions. The production frontier was specified as a translog,

$$
\begin{aligned}
\ln y_{it} = {} & \alpha_0 + \Sigma \sum_{k=1}^{8} \beta \ln x_{kit} \\
& + \frac{1}{2} \sum_{k=1}^{8} \sum_{j=1}^{8} \alpha_{kj} \ln x_{kit} \ln x_{jit} \\
& + \delta_t t + \frac{1}{2} \delta_{tt} t^2 \\
& + \sum_{k=1}^{8} \delta_{kt} \ln x_{kit} t \\
& + v_{it} - u_{it}
\end{aligned}
$$

Where y is output, $x_k$ are inputs, t is a time trend and $\alpha, \beta, \delta$ are parameters to be estimated. The selection and definition of variables are similar to those employed in analysis of dairy production by Hallam e Machado (1996) for Portugal and Hadley (2006) for England and Wales.. Output, feed, other variable inputs, stock of capital, are all defined in value. Output and Input variables defined in value terms are deflated to 2005 prices using published price indices. Herd and land are defined in physical terms and a quota dummy variable is included. The statistics of the sample indicate some heterogeneity in the data as reported in table 2. An average dairy farm has 24 hectares and 26 cows but with a standard deviation of 22

Ha and 16 cows respectively there is a wide range in farm size. Production per hectare is on average 6376 litres with a standard deviation of 3602 litres. The data reflects some heterogeneity across farms as well as the change in average farm size and average production over a long period. Apart from structural change the data also reflects change in policy with the introduction of dairy quotas being the major one affecting farmer's behaviour.

Three different model specifications were estimated. The first defines output in value terms including subsidies, the second defines output in value terms excluding subsidies and the third introduces two dummy variables for 1999 and 2000.This dummy variables account for changes in the perception of the policy environment and uncertainty whether a super levy due to over quota production would be payable.  Parameter estimates for the three model specifications are reported in Appendix Table 3. The overall explanatory power of the equations is good, as shown in Table 4 the value of the Wald statistic allows us to reject the hypothesis that the parameters are zero, and of the 24 parameters estimated in each equation more than half are significantly different from zero for a 95% confidence interval.

Output elasticities and returns to scale are summarised for the three model specifications in Table 5. As shown in figure 1 for the first model specification output elasticities with respect to land, cows, feed, variable inputs and capital are positive as expected. The scale elasticity is equal to 0.98. The mean elasticities of output with respect to inputs for the second specification, which differs only in the output variable with and without subsidies, are all positive except land and the scale elasticity 0.76 is much smaller. Mean elasticity of output with respect to feed and to capital are negative in the third model specification when annual dummies accounting for the first years of possible over quota production are introduced. As expected the effect of quota restrictions shift the production frontier backwards and the quota parameters are significantly different from zero except in the model specification excluding subsidies. The two dummy variables for 1999 and 2000 are negative and significantly different from zero for any level of significance.

The rate of technical change is calculated from

$$\frac{\delta \ln y}{\delta \ln t} = \delta_t + \delta_{tt} t + \sum_k \delta_k \ln x_k$$

Technical change is defined as the percentage change in output due to an increment in time and can be decomposed into two components, pure technical change $\delta_t + \delta_{tt} t$ and non neutral technical change $\sum_k \delta_k \ln x_k$.

The mean rate of technical change which describes the movement of the production function through time is negative for the three model specifications contrary to expectation. The rate of technical regress is on average 2% per year for the first model specification but is decreasing overtime reaching positive values from 2001 onwards as shown in Figure 4. Decomposing it one obtains a negative value for the neutral component, -0.19, and a positive value of 0.17 for non neutral technical change. Heshamati and Kumbhakar(1997) discussing a similar case argue that the effects of increasing inefficiency over time may be partially captured in the estimates of technical change. Another possible cause might be the unfavourable trend in the milk price over the period in analysis.

The hypothesis that technical inefficiency is increasing with time can not be rejected at the 95% probability level since the values for the eta parameter, see Table 4, are negative in the all the model specifications. Overall, the magnitude of the predicted mean efficiencies for the first model specification indicates that the farms in the sample operate at low levels of efficiency. The range of scores for the first model specification, as shown in Figure 5, range from 30% to 90% with most of the observations falling bellow 60% and just 6% of them scoring above. Average efficiency is 50% which when compared with previous studies are vey low values. Silva (2002) using DEA for a sample of 122 farms reports an average of 63%. Apart from the differences between a non-parametric and a parametric methodology the output in Silva model is defined as litres of milk produced. However the introduction of two dummy variables accounting for the first two years when quota become binding and there was great uncertainty whether a super levy would be payable change the results for technical efficiency completely. Average efficiency is now 84% with the distribution shown in Table 6 and graphically represented in Figure 6.

## 4. Discussing heterogeneity and efficiency measurement

The question of heterogeneity is usually addressed in the context of technological heterogeneity or heterogeneity in economic behaviour. In modelling production technology we almost always assume that all producers use the same technology. In this context when we select a sample of specialist dairy farms, farm type 4110 in FADN, we choose farms which we expect have the same technology. Recently some studies have admitted a mixture of several technologies combining a latent class structure with a stochastic frontier approach, Orea and Kumbhakar(2003)

We also assume that farmers in the sample behave in the same way either as profit maximizers or as cost minimisers. Although using the same technology some producers cannot adjust output to the profit maximizing level due to quota restrictions.
A third source of heterogeneity is due to the composition of the sample like the existence of outliers, differences due to farm location, farm size. The exclusion of outliers in the sample affects the parameter estimates as well as the average efficiency. The difference between heterogeneous and homogenous samples is reflected in the distribution of efficiency scores, a tight distribution like the one displayed in figure 5 for Azorean farms reflects its homogeneous nature.

Using data panel over a long period, 1988-2005, also introduces some heterogeneity which is dealt allowing for technical change in the model and for time variant technical change. Greene(2002) argues that in lengthy panels assuming that inefficiency is time invariant forces cross unit heterogeneity into the term used to capture inefficiency. However as technical change is captured by a time trend it is possible that some of the effects of increasing inefficiency were captured in the estimates of technical change. The decomposition of technical change into a neutral and non-neutral component shows that it is the negative value of the component associated with the time trend that explains the rate of technical regress estimated in this case.

Using the more robust model specification average efficiency is 84%, well above previous estimates. The proportion of farms in the sample with average efficiency scores above 80% is close to 71%. Close proximity of the majority of Azorean dairy farms to the production frontier had not been reported in previous studies. Only in 8% of the farms in the sample technical inefficiency was found to be high and it is expected that these farms will remain inefficient unless some structural change takes place. Thus in a scenario of change in the quota regime, and a probable negative shock for milk prices, the farms with persistent inefficiency are likely to go out of business first but the majority has a high probability of staying in business.

The rate of technical change while positive from 2001 onwards is on average negative. The results obtained raise some questions about the possible interaction between the time trend variable and the inefficiency component of the error term. It is not easy to identify what can be attributed to technical change and to technical inefficiency.

## 5. Open questions and summary

The F.A.D.N. data analysed here represents the second dairy producing region in Portugal and includes more than 3 thousand observations over a long period. Previous studies use smaller samples for a single year. The composition of the sample could introduce problems of heterogeneity discussed above and analysed from an empirical point of view to identify how inefficiency measures are affected. This paper has several extensions of previous literature addressing efficiency in the Portuguese dairy sector. First is a parametric approach using a flexible form – a translog. Second allows for technological change and time variance inefficiency. Third allows for policy change- dairy quota- in the model. We have obtained empirical results, production elasticities, elasticity of scale, rate of technical change that increase the information available from previous non-parametric studies. The results for technical efficiency are on average higher than those estimated in previous studies and the hypothesis of time-varying efficiency was not rejected. Further work on the possible relation between the time related component of technical efficiency and technical change in a panel data context is required.

**Appendix**

**Table 1. Average value added per dairy farm(euros)**

| | Small 8-<16 ESU | Medium 16-<40ESU | Large 40-<100ESU |
|---|---|---|---|
| Portugal | 14379 | 42245 | 108208 |
| Azores | 10337 | 30636 | 67318 |

Table 2. Summary of variables statistics

| | | Mean | Std. Dev. |
|---|---|---|---|
| Output | (Euros) | 44,684 | 34,656 |
| Milk | (Litres) | 131,114 | 93,450 |
| Land | (Hect.) | 24 | 25 |
| Cows | (CN) | 26 | 16 |
| Feed | (Euros) | 8,530 | 8,826 |
| Cint | (Euros) | 19,057 | 16,915 |
| Kapital | (Euros) | 93,898 | 111,821 |
| Cows/Hect | | 1.28 | 0.54 |
| Litros/Hect | | 6,376 | 3,602 |
| Litros/Cow | | 4,795 | 1,477 |

**Table 3. Parameter estimates**

| | Dairy Farm(*) | | Dairy Farms(**) | | Dairy Farm (***) | |
|---|---|---|---|---|---|---|
| | Coeficiente | Z | Coeficiente | z | Coeficiente | z |
| Land | -0.0333356 | -0.24 | 0.1053105 | 0.71 | -0.13 | -1.1 |
| Cows | -0.5182359 | -2.31 | -0.8783841 | -3.8 | 0.947 | 4.6 |
| Feed | -0.0871805 | -0.8 | 0.1498617 | 1.3 | 0.022 | 0.23 |
| O. inputs | 1.024479 | 6.6 | 0.9524876 | 5.9 | 0.132618 | 0.92 |
| Capital | 0.7102308 | 8.95 | 0.7128505 | 8.5 | 0.1355357 | 1.81 |
| Land*Cows | -0.1135061 | 5.77 | -0.0770445 | -3.66 | -0.038 | -2.2 |
| Land*Feed | 0.0165583 | 0.79 | -0.0082944 | -0.37 | -0.012 | -0.69 |
| Land*Cint | -0.0059611 | -0.2 | 0.0300051 | 0.94 | -0.0174 | -0.66 |
| Land*k | 0.029465 | 1.51 | -0.0011887 | -0.06 | 0.0497 | 2.9 |
| Cows*feed | 0.0094336 | 0.41 | 0.0603268 | 2.42 | 0.036 | 1.85 |
| Cows*Cint | 0.0210842 | 0.61 | -0.0751296 | -2.03 | -0.026 | -0.86 |
| Cows*Capital | 0.1033037 | 4.1 | 0.1552176 | 5.8 | -0.0189 | -0.84 |
| Feed*Cint | 0.0238093 | 3.51 | 0.0272695 | 3.84 | 0.0183 | 3.07 |
| Feed*capital | -0.0067837 | -0.57 | -0.0342033 | -2.74 | -0.0143 | -1.34 |
| Cint*Capital | -0.1026703 | -7.54 | -0.0802942 | -5.71 | -0.0067 | -0.53 |
| T | -0.2383971 | -10.13 | -0.2475451 | -9.97 | -0.111 | -5.14 |
| T*T | 0.0046835 | 16.22 | 0.0031933 | 11.17 | 0.0016 | 6.03 |
| Land*T | 0.0008044 | 0.29 | -0.0146743 | -4.95 | 0.005 | 2.04 |
| Cows*T | -0.0249396 | -5.78 | -0.0081486 | -1.79 | -0.0117 | -3.05 |
| Feed*T | -0.0052758 | -2.41 | -0.0087074 | -3.78 | -0.00244 | -1.25 |
| Cint*T | 0.0213242 | 6.37 | 0.0240908 | 6.94 | 0.0109 | 3.56 |
| K*T | 0.0081431 | 4.1 | 0.0080281 | 3.8 | 0.00174 | 0.98 |
| Const | 1.175236 | 1.86 | 0.7482218 | 1.09 | 5.92 | 10 |
| Quota Dummy | -0.3643967 | -16.08 | 0.0143936 | 0.8 | -0.083 | 3.65 |
| Dummy 1999 | | | | | -0.92 | -27 |
| Dummy 2000 | | | | | -0.91 | -26 |

(*) excluding outliers (**) Product without subsidies (***) Quota Dummies

Table 4. Model statistics

| | LL | Wald | Sigma u | Sigma v | Gama | Eta |
|---|---|---|---|---|---|---|
| Dairy(*) | 304 | 15621 | 0.028 | 0.033 | 0.44 | -0.14 |
| Dairy(**) | 119 | 23579 | 0.036 | 0.039 | 0.44 | -0.07 |
| Dairy(***) | 608 | 36503 | 0.07 | 0.028 | 0.71 | -0.03 |

(*)excluding outliers (**)Product without subsidies (***)Quota Dummies

Table 5. Average Elasticity

| | **Dairy Farm(*)** | **Dairy Farm(**)** | **Dairy Farm(***)** |
|---|---|---|---|
| Land | **0.03** | **-0.07** | **0.03** |
| Cows | **0.34** | **0.36** | **0.58** |
| Feed | **0.09** | **0.11** | **-0.02** |
| O.Inputs | **0.34** | **0.17** | **0.19** |
| Capital | **0.15** | **0.19** | **-0.06** |
| Scale Elasticity | **0.98** | **0.76** | **0.73** |

(*)excluding outliers (**)Product without subsidies (***)Quota Dummies

Table 6. Distribution of efficiency ranking in Dairy Farm with quota dummies

| | 50-60 | 60-70 | 70-80 | 80-90 | >90 |
|---|---|---|---|---|---|
| Freq, | 28 | 188 | 562 | 980 | 896 |
| % | 1.1 | 7.1 | 21.2 | 36.9 | 33.8 |

## Figure 1. Elasticity estimates for dairy farms model, Without outliers

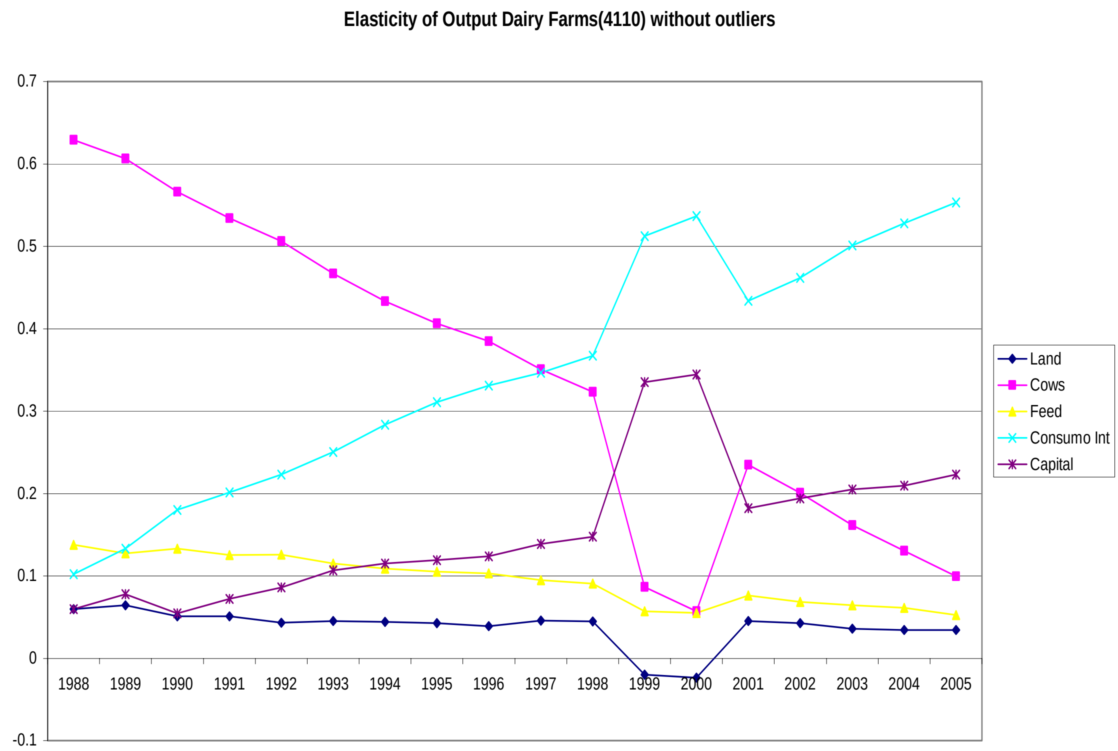


**Figure 2. Elasticity estimates for dairy farms without subsidies model**

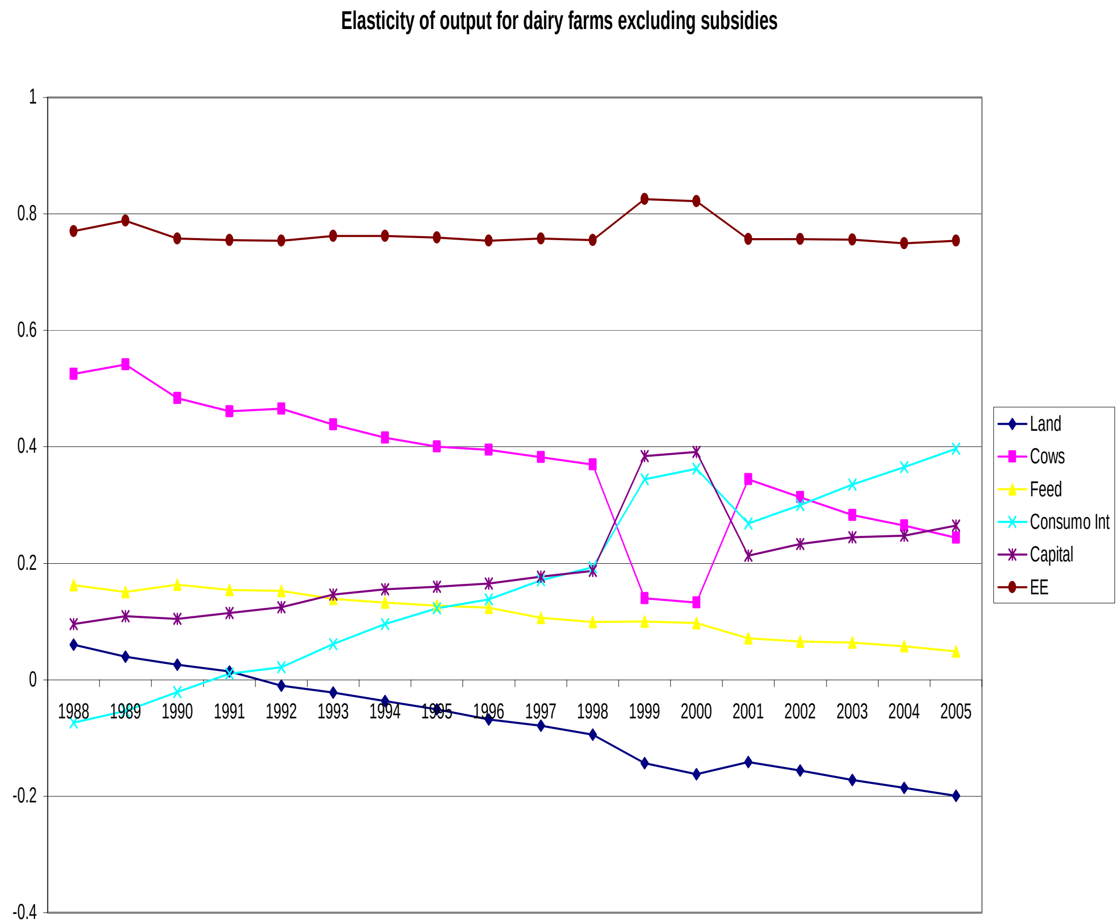


**Figure 3. Elasticity estimates for dairy farms (4110) with quota dummies**

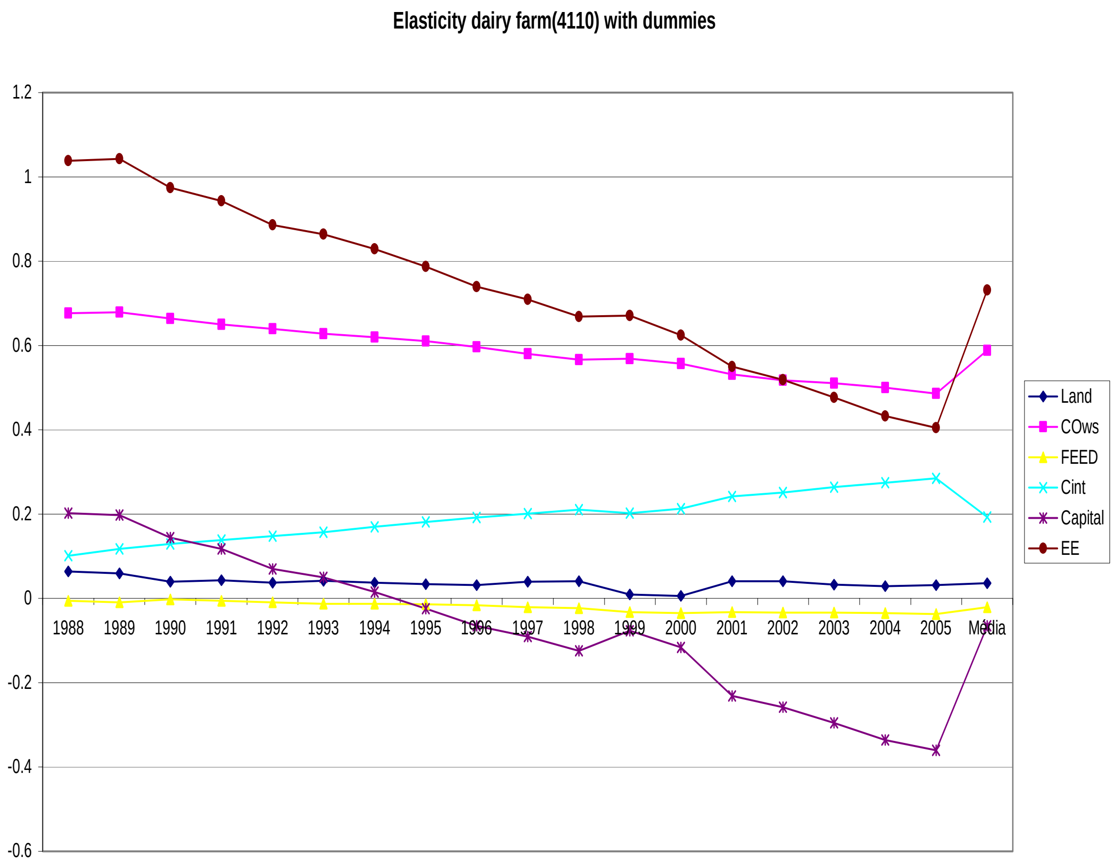


**Figure 4. Rate of technical change in the dairy farm model without outliers**

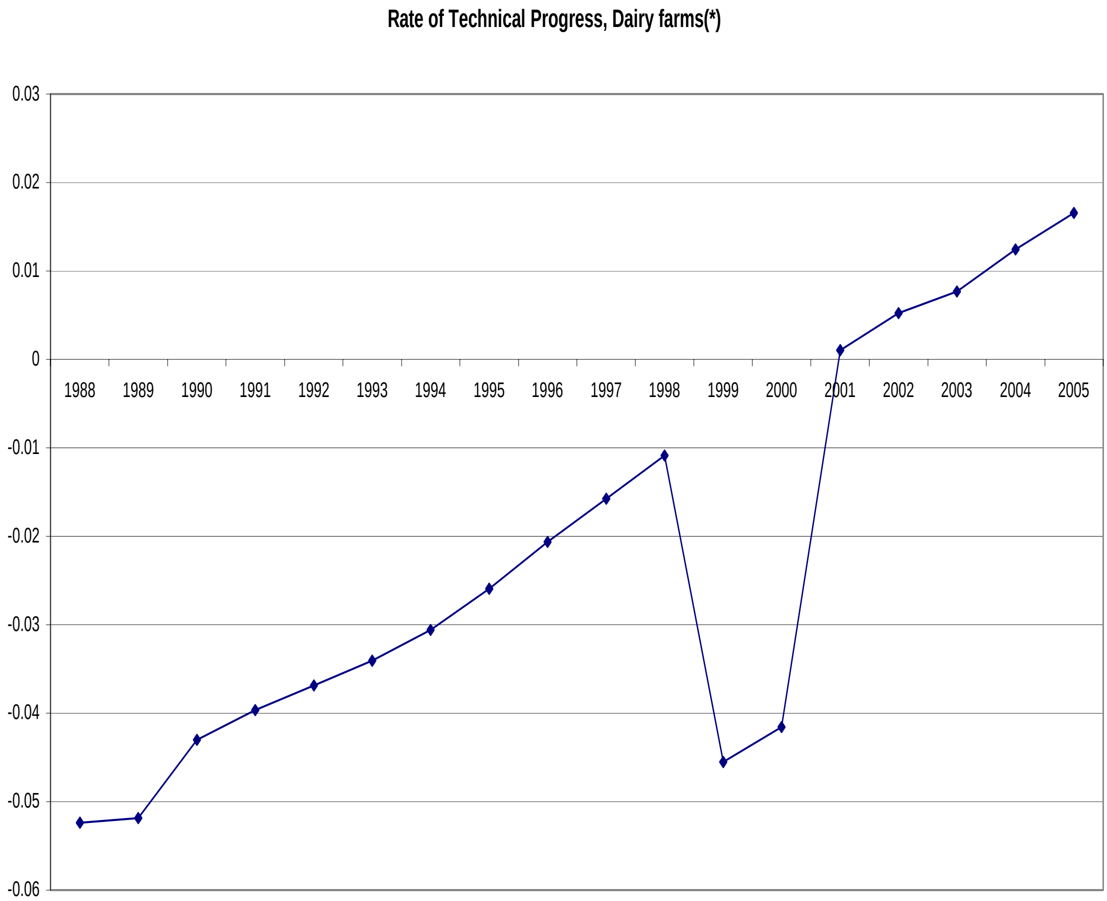


Figure 5.Distribution of technical efficiency

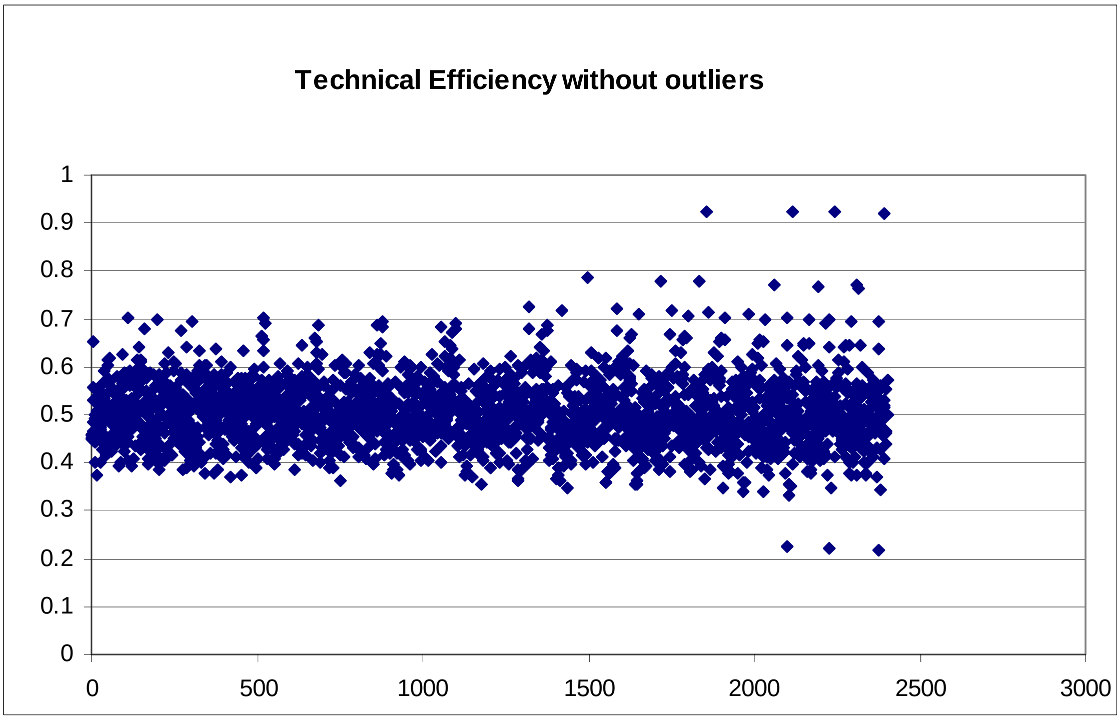



Figure 6. Technical Efficiency Dairy Farm with quota dummies

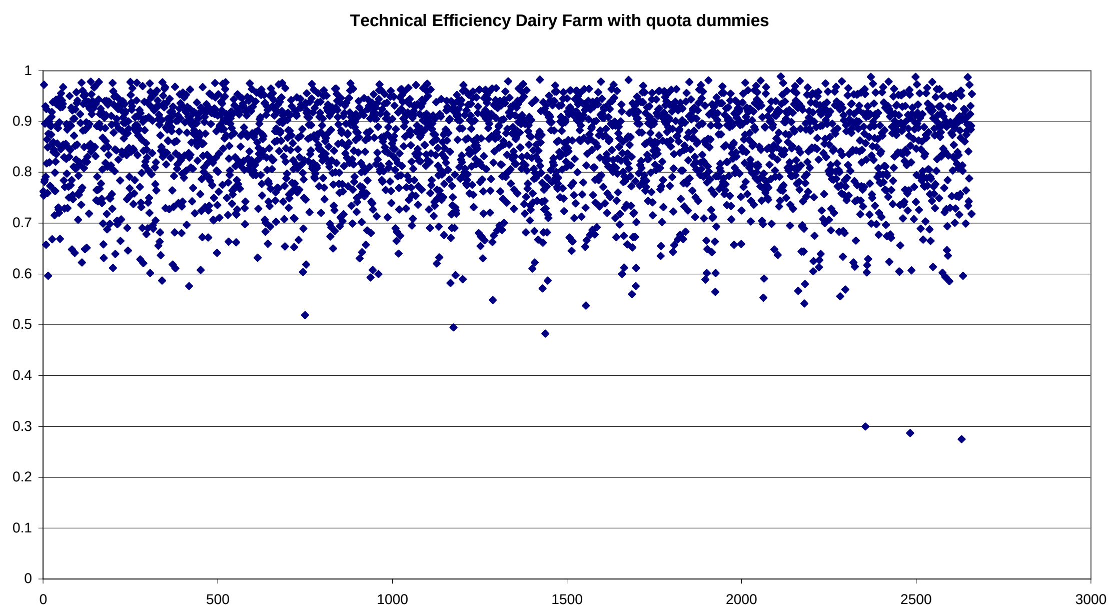
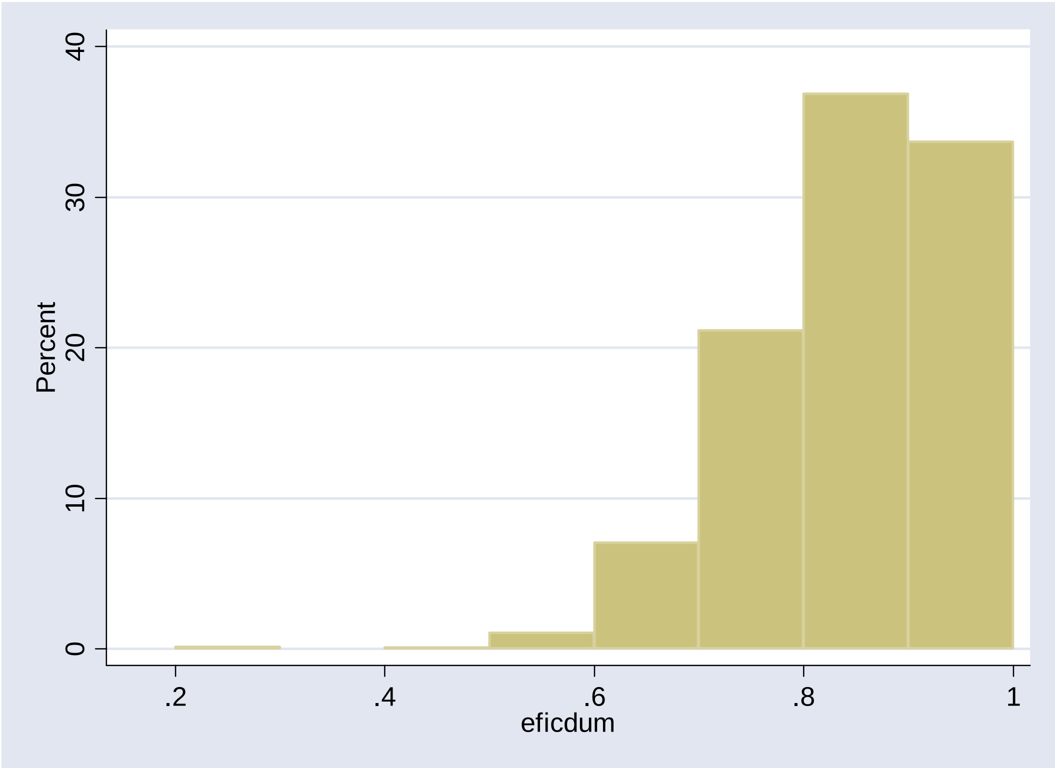
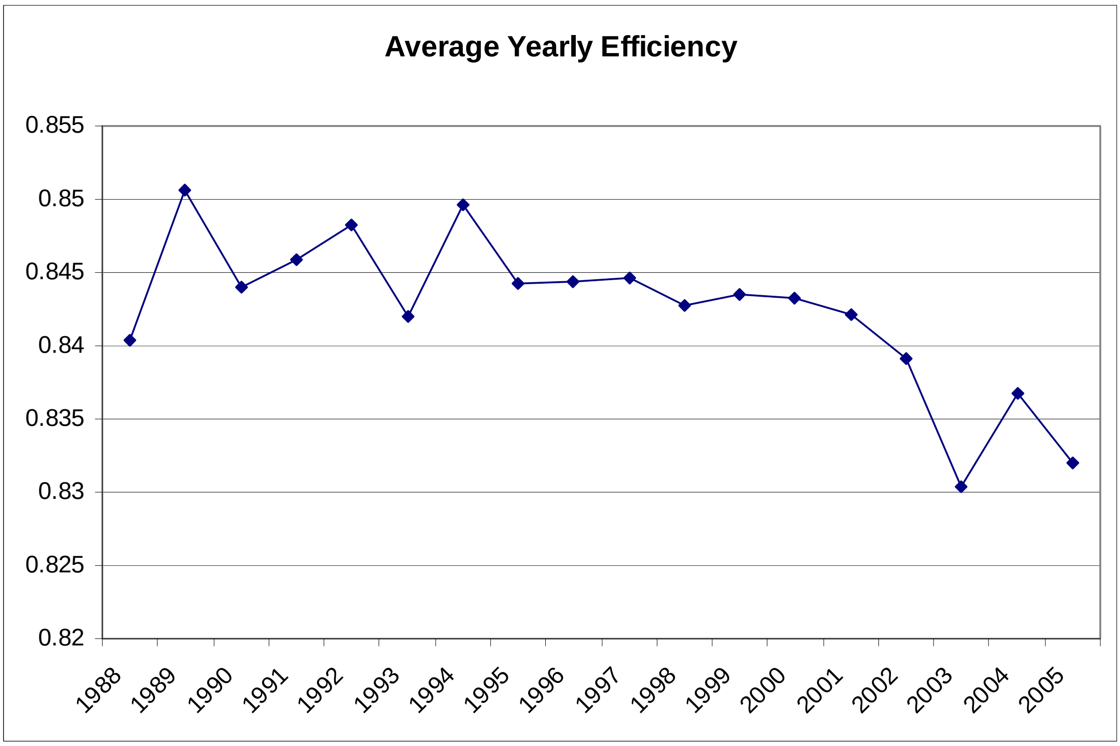


**Figure 7. Distribution of Technical efficiency index**



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