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EXPLAINING DIFFERENCES IN MILK QUOTA VALUES. THE ROLE OF ECONOMIC EFFICIENCY

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Abstract: This paper explores the relationship between milk quota values and economic efficiency in order to analyze current government interventions in quota allocations among producers. For this purpose, we estimate a short-run variable cost function using a panel of Spanish dairy farms. Quota values are then decomposed into economic efficiency, price, and scale effects in order to assess the relative influence of these factors on quota values. We find that efficiency is important in explaining quota values but is uncorrelated with observable farm characteristics. This casts doubts on the government's ability to allocate quotas to efficient farms in the way a well-functioning quota market does.

Keywords: cost function, economic efficiency, milk, quota values.

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1. Introduction

Most agricultural price support programs have provided incentives for greater production, excess supplies and financial burdens on governments. As a consequence, various forms of supply control have come to be associated with price supports (see Alston, 1992). A specific form of supply limitation is the use of *quotas* applied to individual producers, which constrain the amount sold by farmers.

One of the most notable applications of quotas is the European Union policy introduced in 1984 limiting milk production. By that time, the system of guaranteed prices had created large government stocks of butter and powdered milk that consumed a significant part of the EU budget. Not surprisingly, this policy has generated a great deal of interest among economic analysts (e.g., Burrell, 1989a). More recent empirical work has been carried out by Guyomard et al. (1996), Boots et al. (1997) and Colman et al. (2002).

The analytics of the effects of a quota policy (e.g., Dawson, 1991; Fulginiti and Perrin, 1993) suggest that by restricting quantities supplied, the imposition of quotas generates economic inefficiency relative to a free market policy, though quotas could improve efficiency relative to price supports, especially in the case of transferable quotas (Alston, 1981). Moreover, it has been argued that if quotas are freely tradable, more efficient farmers will buy quota from less efficient farmers, the result of this exchange being that the global quota is produced at minimum cost (Burrell, 1989b; Oskam and Speijers, 1992). For this reason, milk quota transfers have been allowed in the EU since 1987, although trading rules differ across member states.

This paper presents an analysis of dairy production quotas in Spain. Unlike the situation in other EU countries where quota markets are well developed, notably the United Kingdom and the Netherlands (see Pennings and Meulenberg, 1998), in Spain there are presently few milk quota agents whose services reduce the transactions costs for producers willing to buy, sell, or rent quota. Therefore, the quota market is thin and transactions are rare. The Spanish government plays an important role in the quota reallocations through the redistribution of the quota from milk retirement programs. However, it is not clear whether the redistribution of the quota acquired through these programs is allocated to the most efficient farmers and therefore contributes to increasing the sector's efficiency.

In our empirical application we estimate quota values for a sample of 71 Spanish dairy farms. An important feature of our model is that the marginal cost function differs across producers depending on their economic efficiency levels.[1] Then, we decompose the differences in quota values into scale, price and efficiency effects. This decomposition has a methodological contribution. While previous decompositions rely on (average variable) cost functions, our decomposition relies on a marginal cost function and uses both Diewert's (1976) Quadratic Identity Lemma and a Malmquist-type procedure to decompose changes in marginal costs. Additionally, our model allows the inefficiency term to be explained by certain observed variables, allowing us to explore the existence of variables that can be used as proxies for efficiency.

Our results on the role of efficiency in quota value are important for understanding the effects of government interventions in quota allocation. While a well-functioning quota market tends to allocate quota to efficient producers, the allocation of quota by the government faces an important problem: efficiency is unobservable[2] and not necessarily correlated with any observed farm characteristic. Therefore, government intervention can result in quota being allocated to inefficient farmers. Using simulation analysis, we provide some evidence of this phenomenon in the Spanish dairy sector.

The structure of the paper is as follows. We start by reviewing the standard analytics of calculating milk quota values. Next we discuss the data and the empirical analysis. Then, the estimates of quota values and their decomposition are presented. Some implications of the results for public policy are illustrated by simulating quota trade in a well functioning market. The final section of the paper contains a summary and some conclusions.

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[1] The literature on quotas usually refers to efficiency in the marginal sense. That is, more efficient farmers are those that produce at a lower marginal cost. However, we consider efficiency in the Farrell (1957) tradition where more efficient farmers produce at a lower cost for any level of output.

[2] When we say that efficiency is unobservable, we mean that it is not readily observable (as are the number of cows or hectares of land). Obviously, it can be calculated. We use the word unobservable in the sense that it is used in the econometric literature that refers to "unobservables" as those variables that are difficult to measure by simple means (ability, intelligence, genetic level,...) though they can be estimated somehow.

2. The value of milk quota

A policy of limiting total production through the allocation of quotas adds a constraint to the optimizing behavior of producers which may be represented in terms of profit maximization:

$$\begin{aligned} &\max_{y} \Pi_i = P_i y_i - C(y_i, w_i, z_i) \\ &\text{s.t.} \quad y_i \leq \overline{Q}_i \end{aligned} \tag{1}$$

where Π_i denotes the profit of producer i, y_i is output, P_i is output price, w_i is the input price vector, z_i is the vector of quasi-fixed inputs, $C_i(\cdot)$ is the variable cost function, and $\overline{Q}_i$ is the milk quota. The solution to this optimization problem can be found using the familiar Lagrangean formulation:

$$L = P_i y_i - C(y_i, w_i, z_i) + \lambda_i(\overline{Q}_i - y_i) \tag{2}$$

where λ_i is the Lagrangean multiplier. The first order condition (FOC) can be obtained by differentiating expression (2) with respect to output. Since the quota constraint may not be binding, the Kuhn-Tucker conditions are the appropriate FOC (see Babcock and Foster, 1991). However, in our sample most farms are producing near the quota constraint. Thus, the relevant FOC is:

$$P_i - MC(y_i, w_i, z_i) - \lambda_i = 0 \tag{3}$$

where $MC=\partial C(\cdot)/\partial y$ denotes marginal cost. The optimal value of the Lagrange multiplier λ_i is the shadow value of the quota for producer i. This multiplier measures the change in the objective function (profit) when there is a unit change in the constraint (quota). In other words, it is the marginal profit of quota.[3]

From equation (3) it follows that the value of the milk quota for each price-taking producer is estimated as the difference between price and marginal cost evaluated at the quota level:

$$\lambda_i = P_i - MC(\overline{Q}_i, w_i, z_i) \tag{4}$$

[3] Quotas may also be valued by farmers because they contribute to reducing price uncertainty (Moschini, 1984). We do not consider uncertainty issues in this analysis.

We now introduce economic inefficiency into this model. Let the short-run variable cost frontier be denoted by $C^*(y_i,w_i,z_i)$. Observed variable costs will be higher than $C^*(\cdot)$ when farms are technically and/or allocatively inefficient. Following Farrell (1957), economic efficiency can be measured as the ratio of minimum to observed cost:

$$EE_i = \frac{C^*(y_i, w_i, z_i)}{C_i} \tag{5}$$

Rearranging expression (5), and taking first derivatives with respect to output, the *observed* marginal cost (*MC*) for an inefficient farm can be written (assuming that efficiency is independent of output) as:

$$MC_i = MC^*(y_i, w_i, z_i) \cdot EE_i^{-1} \tag{6}$$

where $MC^*(\cdot)=\partial C^*(\cdot)/\partial y$ is the *efficient* marginal cost. Expression (6) allows producers to differ in marginal cost levels not only due to the quantities of output, input prices, and quasi-fixed inputs, but also due to different levels of economic efficiency: the higher the efficiency level, the lower the farm's marginal cost[4].

Hence, replacing MC(·) in equation (4) by expression (6), the shadow value of quota for producer *i* can be expressed as:

$$\lambda_i(P_i, \overline{Q}_i, w_i, z_i, EE_i) = P_i\text{-}MC^*(\overline{Q}_i, w_i, z_i) \cdot EE_i^{-1} \tag{7}$$

An important feature of expression (7) is that economic efficiency (EE_i) appears as a component of quota values. This insight has been overlooked in previous papers, which have centered mainly on the role of quota levels ($\overline{Q}_i$) in quota values (one exception is the paper by Lansink, 2003).

3. Data and empirical model

The introduction of quotas in Spain, after joining the EEC in 1986, may have accelerated the transformation of the sector from numerous small producers to fewer and larger producers (see Table 1). The Spanish case is consistent with the experience in the rest of the European Union, where the number of dairy farms and cows has been decreasing while the production per farm and per cow has been increasing. In this section we estimate quota values using a balanced panel data set for the years 1993 to 1998 of 71 Spanish dairy farms. Some summary statistics of the data set are shown in Table 2. Over the sample period, the farms in the panel have grown in quota levels due to both quota transfers from other producers as well as to allocations from the national reserve. The number of cows has increased while land has remained almost constant. Two important characteristics of dairy farms, namely the stocking rate and cow productivity, have also increased during the sample period.

Since marginal cost is unobservable, it is necessary to first estimate a cost function and then obtain the marginal cost curve analytically by taking the derivative of cost with respect to milk production.[5] This is the methodological approach used by Guyomard et al. (1996). Alternatively, other authors have used a restricted profit function (Helming et al., 1993). In order to allow efficiency to be a determinant of marginal cost, we estimate the following *translog* variable cost frontier, which includes as arguments the level of output (*y*=milk), a quasi-fixed input (*z*=land), a variable input price (*w*=feed price), and a set of time-dummy variables (*D*) to capture both technical change and also the effect of any other variables (such as input prices) that are common to all producers and which vary over time. We also estimated the cost function with one more output (livestock output) and with more quasi-fixed inputs (labor, capital). Since they were not significant, we present the simplest model, which only includes one output, one quasi-fixed input and one input price.

$$\begin{aligned} \ln C_{it} = & \Big[\beta_0 + \textstyle\sum_{t=1}^{T} \beta_t D_t + \beta_y \ln y_{it} + \beta_z \ln z_{it} + \beta_w \ln w_{it} \\ & + \frac{1}{2}\beta_{yy}(\ln y_{it})^2 + \frac{1}{2}\beta_{zz}(\ln z_{it})^2 + \frac{1}{2}\beta_{ww}(\ln w_{it})^2 \\ & + \beta_{yz} \ln y_{it} \ln z_{it} + \beta_{yw} \ln y_{it} \ln w_{it} + \beta_{zw} \ln z_{it} \ln w_{it}\Big] + v_{it} + u_{it} \end{aligned} \tag{8}$$

where subscripts *i* and *t* stand for farms and time; the term in brackets is the logarithm of the deterministic variable cost frontier, $lnC^*(\cdot)$; v_{it} is a symmetric random noise term

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[4] Using this formulation, marginal costs are farm-specific. One referee pointed out the similarities with farm-specific netput shares in Gardebroek and Lansink (2003).

[5] There are alternatives to this approach. When there is a well-functioning market for quotas, which is not the case in Spain at present, Babcock and Foster (1992) suggest using the market price of the quota as an estimate of marginal cost. On the other hand, Hubbard (1992) considers long-run marginal cost to be constant (and therefore equal to average cost), using survey data to calculate it.

normally distributed with zero mean and variance σ_v^2; and u_{it} is a non-negative inefficiency term.

The correct estimation of stochastic frontier models is far from simple. Caudill and Ford (1993) have shown that frontier parameters are biased if the inefficiency term is heteroskedastic. Wang and Schmidt (2002) show that the efficiency scores are also biased. Some models have been developed that take this problem into account, such as the widely-used model introduced by Battese and Coelli (1995). However, an important limitation of these models is that they assume independence over time of the efficiency term. That is, the panel structure of the data is not fully exploited. As a result, it is not possible to estimate the inefficiency level consistently since its variance does not vanish as the sample size increases.

For this reason, we propose using an alternative model, which allows for firm-specific heteroskedasticity, [6] while exploiting the advantages of panel data.[7] In this model, the inefficiency term u_{it} is the product of a function of some variables and a non-negative, time-invariant but firm-specific efficiency term, u_i. That is:

$$u_{it} = g(x_{it}, \delta) \cdot u_i = \exp(\delta' x_{it}) \cdot u_i \quad , \quad u_i \geq 0 \tag{9}$$

where $\delta = (\delta_1, \ldots, \delta_k)$ are parameters and $x_{it} = (x_{1it}, \ldots, x_{kit})$ is a vector of k variables that are assumed to be correlated with the efficiency level. The choice of the x variables is difficult. Several farm management indicators (such as milk quality, milk per cow, etc.) were included in the model, but they were not significant. The only two variables that turned out to be significant were a time trend (x_1), which captures common changes in farms' efficiency, and the number of cows per hectare (x_2).

The stochastic cost frontier with the inefficiency term modeled as in (9) can be estimated by maximum likelihood. In our empirical application we have assumed for u_i a half-normal distribution with zero mean and variance σ_u^2. Once the cost function is estimated, the calculation of marginal quota values is a straightforward application of equation (7), where economic efficiency can be calculated as $EE_{it}=exp(-u_{it})$. Marginal

[6] We have carried out a LR test in order to check the validity of the homoskedastic model. This hypothesis was rejected.

[7] This model has already been employed in Orea and Kumbhakar (2004) in the context of a latent class stochastic frontier model in a panel data framework.

costs depend on the levels of quota, the fixed input, the input prices, and on the farm's inefficiency level. Subtracting the calculated marginal cost from the observed output price yields the producer-specific marginal quota value.

4. Decomposing quota values

The objective of this section is to decompose differences among the quota values calculated for different producers into a set of economically meaningful components. To carry out this decomposition we have to address three issues that have not been previously analyzed in the literature. First, while previous decompositions rely on cost functions, our decomposition relies on marginal cost. Second, decomposing marginal cost requires the decomposition not only of changes in costs but also of changes in a scale elasticity measure. While the first decomposition relies on the well-known Diewert (1976) Quadratic Identity Lemma, the latter has not been addressed in the literature. Here we propose using a Malmquist-type procedure. Third, we use a first-order Taylor approximation of the quota value function to establish a link between quota values, which are defined in levels (i.e. without taking logs), and the natural logarithm of marginal cost due to the choice of a Translog form for the variable cost function.

The details of the decomposition are shown in the Appendix. The object of interest for the decomposition is the difference between the quota value of farm *i* and a suitably chosen farm for comparison (*j*). We choose farm *j* to be the farm with the highest quota value in the sample, which is used as a benchmark to analyze the relative importance of each component for the quota value for each farm. The final decomposition can be written as:

$$\begin{aligned}
\lambda_i - \lambda_j \approx\ & P_j \cdot \left(\ln P_i - \ln P_j\right) + MC(j) \cdot \left[\ln EE_i - \ln EE_j\right] \\
& - MC(j) \cdot \left\{ \frac{1}{2}\left[\left(\varepsilon_y(i) - 1\right) + \left(\varepsilon_y(j) - 1\right)\right] \cdot \left(\ln \overline{Q}_i - \ln \overline{Q}_j\right) + \ln e_{yy}(i,j) \right\} \\
& - MC(j) \cdot \left\{ \frac{1}{2}\left[\varepsilon_w(i) + \varepsilon_w(j)\right] \cdot \left(\ln w_i - \ln w_j\right) + \ln e_{yw}(i,j) \right\} \\
& - MC(j) \cdot \left\{ \frac{1}{2}\left[\varepsilon_z(i) + \varepsilon_z(j)\right] \cdot \left(\ln z_i - \ln z_j\right) + \ln e_{yz}(i,j) \right\}
\end{aligned} \tag{10}$$

where *i* and *j* denote the farm under analysis and the farm used as benchmark respectively, $\varepsilon_y(i)$, $\varepsilon_w(i)$ and $\varepsilon_z(i)$ are the elasticities of variable cost with respect to the output, the input price and the quasi-fixed input respectively; and $lne_{yy}(i,j)$, $lne_{yw}(i,j)$ and $lne_{yz}(i,j)$ measure differences in the logarithm of the output-elasticity of variable cost due to differences in output levels, input prices and quasi-fixed inputs respectively. These differences in elasticities play an important role in our decomposition. Since the elasticity is defined as the ratio of marginal cost to average cost, they allow us to go from decomposing a traditional (average) cost function to decomposing a marginal cost function. This decomposition is illustrated in Figure 1.

The first term on the right-hand side of (10) measures the contribution of differences in output prices (*output price effect*). The second term (*efficiency effect*) captures differences in quota values due to differences in economic efficiency. The third term (*scale effect*), which depends on the average returns to scale of the benchmark and the analyzed farm, measures the effect of quota size. This term takes a negative value in Figure 1 (and also in our empirical application) because the quota level of farm *j* is smaller than that of farm *i* and decreasing returns to scale exist. Since the scale effect depends on scale elasticity values, it vanishes under the assumption of globally constant returns to scale or equal quota levels.[8] The fourth and fifth terms (*input price effect* and *quasi-fixed input effect*) measure differences in quota values due to differences in input prices and quasi-fixed input levels respectively. If marginal costs increase (decrease) with input prices (quasi-fixed input levels), these terms would take a negative value when other farms employ more quasi-fixed input than farm *j* (as is the case in our empirical exercise) or face lower input prices.

5. Estimation and results

The results of the estimation of the stochastic cost frontier by maximum likelihood are shown in Table 3. Since all the explanatory variables were divided by their geometric means prior to the estimation, the first-order coefficients can be interpreted as cost elasticities evaluated at the sample mean. All of them have the expected signs and are statistically significant. Therefore the variable cost function is increasing in output levels and input prices and decreasing in quasi-fixed input levels at the sample mean. The

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[8] It is important to note that changes in average cost and changes in the output elasticity (i.e. the lne_{yy} term) depend on the degree of returns to scale (see the Appendix)

value of the cost elasticity with respect to output is 1.13 (significantly different from one), indicating the existence of decreasing returns to scale.

Turning to the inefficiency model, both variables are significant. A negative sign means that an increase in a variable reduces inefficiency. Therefore, the trend coefficient indicates that inefficiency decreases over time while more cows per hectare is associated with higher efficiency.

In order to calculate the quota values we follow three steps. First, farm-specific indexes of cost efficiency are calculated as $EE_{it}=exp(-u_{it})$. Next, using the estimated parameters of the cost function and the estimated efficiency levels, the marginal cost for each producer is evaluated at the quota level. Finally, the estimated marginal cost is used to compute the marginal quota value for each farmer using expression (7). Table 4 contains the mean values of these variables. The average quota value in real terms decreases over time, which is largely attributable to an increase in marginal costs but also to a slight decrease in the real price of milk. These effects were, in part, compensated by the increase in cost efficiency over the period.

Table 5 shows the relative importance of efficiency, scale, quasi-fixed inputs, and input and output prices in the estimated differences in quota values. The decomposition is calculated using the farm with the highest quota value (λ^*) as the reference. Since the highest quota value always belongs to the same farm, the reference farm is the same in all years. The estimated difference in quota values, $\hat{\lambda} - \hat{\lambda}^*$, is obtained by summing the effect of the five sources.[9]

The most important source of differences in quota values is the level of efficiency, which represents, on average, more than 60% of the total difference. However, the importance of the efficiency effect decreases from 1993 to 1998 because the differences in efficiency levels decrease over time. The second most important source of differences in quota values is the scale effect. Taking into account that the reference farm is small and that marginal costs increase with size due to the existence of

[9] Since these differences are obtained from the parameter estimates and the estimated efficiency, they do not take into account random noise, unlike the observed differences in quota values. Both measures, however, are highly correlated (the correlation coefficient is 0.84).

decreasing returns to scale, this effect is negative indicating that the marginal cost of the reference farm tends to be lower than those of other farms. Since the feed price paid by the reference farm is slightly lower than that paid by other farms, the input price effect is negative, though modest. Regarding the quasi-fixed effect, which unlike the previous effects is positive (except for the last year), other farms tend to have a higher quota value as they generally employ more land than the reference farm and hence tend to produce with lower average and marginal costs.

In summary, our results show that economic efficiency is the most important factor in explaining differences in quota values, with farm size (measured by output) being the second[10]. The problem is that the efficiency levels are, like the quota values, not directly observable and therefore the government cannot use them as a criterion to allocate quotas among farms. Moreover, policymakers may also have other objectives in mind (e.g. favoring young farmers). The problem at hand is nicely summarized by Burrell (1989b): "But if improving efficiency is one of these objectives, the administrative formulae used as proxies for efficiency criteria may perform relatively badly and the administration itself may be costly". So the key point is how to find predictors of efficiency. In our model we found that the stocking rate is correlated with efficiency. In the next section, we use our model to check whether we are able to explain *differences* in efficiency levels among farms.

6. Decomposing efficiency differences

One advantage of our model, where inefficiency is modeled as the product of a function of some observable variables, $g(x_{it},\delta)$, and a time-invariant inefficiency term, u_i, is that it allows us to study whether the observable variables are significantly correlated with inefficiency. We further exploit this feature of the model to study whether this correlation is large enough to use these observable variables as proxies of the unobservable efficiency levels. The index of economic efficiency can be written as:

$$EE_{it} = e^{-\exp(\delta \cdot x_{it}) \cdot u_i} \tag{11}$$

[10] In the long-run, the effect of size would be quite small. Adjusting the short-run scale elasticity by the elasticity of the variable cost with respect to the quasi-fixed input, we get a long-run scale elasticity (evaluated at the geometric mean) of 1.01 (see Caves *et al*, 1981).

where the scaling function g(x,δ)=exp(x'δ) can be viewed as the part of the efficiency level that we can explain, while u_i is the unexplained part. Since inefficiency is unobservable, information about the relative importance of the sources of inefficiency can be a valuable tool for discretionary decisions in quota allocation. This information can be obtained taking logs and then differentiating (11), which yields:

$$d \ln EE_{it} = \ln EE_{it} \left[\sum_{k=1}^{K} \delta_k dx_{kit} + \frac{du_i}{u_i} \right] \tag{12}$$

The expression in brackets indicates that differences in efficiency across farms can be explained by *observable* differences in the efficiency determinants (dx) and *unobservable* differences in farm-specific efficiency levels (du). In order to analyze the relative importance of both the explained and unexplained parts of the overall difference in efficiency levels we focus on the term in brackets (lnEE is just a scaling factor). Table 6 summarizes the decomposition using equation (12).[11] The second column shows the average difference between the efficiency level of each firm and the farm with the highest quota value. The minus sign indicates that the reference farm is more efficient than most other farms. The next columns summarize the term in brackets, i.e. the effect of each of the two efficiency determinants and of the unexplained differences in efficiency levels. Excluding, for obvious reasons, the column corresponding to the time trend, x_1, the next column indicates that the number of cows per hectare, x_2, explains only a small part of the differences in efficiency levels. Therefore, most of the efficiency differences cannot be explained by observable variables. These results suggest an serious difficulty with discretionary quota allocations by the government. In the following section, we explore the effects on efficiency of a well-functioning quota market versus government intervention in quota trade.

[11] Note that the efficiency decomposition in (12) is written in a continuous framework, whereas the quota value decomposition in (10) hinges on the difference (in logs) between the efficiency level of farm *i* and the reference farm *j*. Thus, in order to decompose efficiency differences we had used a discrete approximation of (12).

7. Policy Analysis

In this section, we simulate the effects on farm efficiency of the Spanish government intervention in quota allocation. This intervention has its origins in the milk retirement programs which most EU countries have implemented in order to speed up the adjustment process in the sector. The Spanish government, aiming at increasing the size of the smallest farms, sells the acquired quota at very low prices. We claim that such a policy may easily overlook farm efficiency.

The first step in our analysis consists of simulating the workings of a quota market (Guyomard et al., 1996; Boots et al., 1997). Theoretical models indicate that a well-functioning quota market leads to the equalization of quota values across farms and the minimization of the cost of producing the aggregate quota. Using data from 1998, the last year in the sample, in the simulation we compare the two basic scenarios proposed by Boots et al. (1997): current quota allocation and allocation under unconstrained quota trade. The results of this exercise are presented in Table 7, where the sample is split into two groups of farms depending on the value ('above average' and 'below average') of the following variables: a) efficiency b) current quota c) land d) milk price.

The results show that farms with above (below) average efficiency would increase (decrease) their allocations in a well-functioning market for quotas. Farms which currently have an above average quota would reduce production and farms with above average land would increase quota. It is important to highlight that changes in quota associated with differences in efficiency are, in general, higher than those associated with size, land or milk price. Under unconstrained quota trade, the group of most efficient farms produces a higher proportion of total output. In fact, the average efficiency of farms that increase quota is 0.88 versus 0.77 for farms that decrease quota.

The results of this simulation have to be interpreted carefully. Colman (2000) and Colman et al. (2002) report the existence of important discrepancies between the simulation of a well-functioning quota market and actual market results. These differences can be explained by an array of market imperfections. Using simulation, Boots et al. (1997) find that market regulations and transaction costs affect quota trading. Therefore, we have to acknowledge that this factors can limit the ability of markets to increase the quota of efficient farms. However, for analytical purposes it is reasonable to compare a well-functioning quota market with some form of governmental intervention since both are reasonable policy instruments. In other words, our previous simulation is used as an analytical tool rather than a predictive tool.[12]

The second step is to analyze the effect of government intervention on quota allocation and thus on farm efficiency. Basically, the government offers incentives for abandoning milk production in exchange for the quota of the farms. Then, the government sells the acquired quota below market rates, creating an excess demand for quota. Therefore, the government has to make a discretional decision about which farms get quota. Ideally, the government should allocate quota to bidders with the highest efficiency. However, as shown in the previous section it is difficult to find strong correlation between efficiency and observed variables. In fact, the random (unknown) component of inefficiency is the largest one in our empirical results. As a result, it is reasonable to expect that government officials will have a hard time identifying the most efficient farms.

The price set by the government in 1998 (26 pesetas) is much lower than the equilibrium quota price in our simulation (162 pesetas)[13]. As a result, there is an excess of demand in the quota market that has to be cleared. Our simulation shows that at the price set by the government 69 farms are willing to buy quota, while in the simulation only 38 farms were quota buyers. Since the government has no information about the efficiency level of farms, some quota will probably be allocated to relatively inefficient farms.

Therefore, the conclusion of this analysis is that discretional decisions on quota allocation are likely to be misguided in terms of efficiency, giving the difficulties of hand-picking efficient farms. Since in a well-functioning quota market the most efficient farms

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[12] Another limitation of this type of analysis is that we are simulating the effects of a single policy measure. Boumra-Mechemache et al. (2002) found that partial market liberalization is not necessarily welfare enhancing in a second best world with multiple interrelated policies.

[13] This value is calculated as the discounted sum of the equilibrium rental value over the duration of the quota regime (until 2015, so far). The discount rate used is 5%.

increase their share of total quota, policies aiming at facilitating quota trade can play an important role in enhancing farm efficiency.

8. Conclusions

This paper estimates quota values for a sample of Spanish dairy farms using a variable cost function that differs across farms due to their economic efficiency levels. Then, the estimated quota values are decomposed into price, economic efficiency, size, input prices and quasi-fixed inputs effects. The main finding of the paper is that economic efficiency is far more important than size in explaining quota values. In fact, farm size, a frequent focus of agricultural policy, is negatively correlated with quota value.

These results raise some doubts about government interventions that allocate quota to farms without considering their economic efficiency. In principle, the government should allocate quota to farms with the highest efficiency. Since efficiency is not observable, the government should rely on observable variables correlated with it. However, we were not succesful in finding those variables, so it is reasonable to expect that government officials will have considerable difficulties identifying the most efficient farms.

By simulating a well-functioning quota market we show that large farms would decrease their total quota, while efficient farms would increase production. Therefore, market quota interventions that look only to enhance farm size can result in quota being allocated to inefficient farmers. In conclusion, a system of quota auctions could permit quota to be allocated to farmers with the highest shadow value.

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Appendix

Let us begin the decomposition of the quota values by establishing a link between quota values and the natural logarithm of marginal cost, which is quite convenient due to the choice of a *translog* form for the variable cost function.

The value of the quota can be written as a function of natural logarithms of prices (P) and marginal cost (MC):

$$\lambda(\ln P, \ln MC) = \exp(\ln P) - \exp(\ln MC) \tag{A1}$$

The partial derivatives of this function evaluated at an arbitrary point ($\ln P_0$,$\ln MC_0$) are:

$$\frac{\partial \lambda}{\partial \ln P}(\ln P_0, \ln MC_0) = \exp(\ln P_0) = P_0$$

$$\frac{\partial \lambda}{\partial \ln MC}(\ln P_0, \ln MC_0) = -\exp(\ln MC_0) = -MC_0 \tag{A2}$$

Finally, the first order Taylor approximation is given by:

$$\lambda(\ln P, \ln MC) \approx \lambda_0 + P_0(\ln P - \ln P_0) - MC_0(\ln MC - \ln MC_0) \tag{A3}$$

where

$$\lambda_0 \approx \lambda(\ln P_0, \ln MC_0) = \exp(\ln P_0) - \exp(\ln MC_0) = P_0 - MC_0$$

Using the highest quota value in the sample as an approximation point, i.e. $\lambda_0=\lambda_j$, the approximation to the quota value of producer *i* can then be written as:

$$\lambda_i \approx \lambda_j + P_j \cdot \lfloor \ln P_i - \ln P_j \rfloor - MC_j \cdot \lfloor \ln MC_i - \ln MC_j \rfloor \tag{A4}$$

The object of interest for the decomposition is the difference between the quota values of farm *i* and farm *j*. This can be obtained trivially from expression (A4) as:

$$\lambda_i - \lambda_j \approx P_j \cdot \lfloor \ln P_i - \ln P_j \rfloor - MC_j \cdot \lfloor \ln MC_i - \ln MC_j \rfloor \tag{A5}$$

This expression indicates that differences in quota values between two firms can be explained in terms of differences in the logarithms of prices and marginal costs. Using equation (6), the efficient marginal cost is:

$$MC^*(Q_i, w_i, z_i) = \left[\frac{C^*(Q_i, w_i, z_i)}{\overline{Q}_i} \cdot \varepsilon_y(Q_i, w_i, z_i) \right] \tag{A6}$$

where ε_y is the elasticity of variable cost with respect to output. Using expression (A6), we can decompose the second term in (A5) as follows:

$$\ln MC_i - \ln MC_j = \left[\ln AC^*(i) - \ln AC^*(j)\right] + \left[\ln \varepsilon_y(i) - \ln \varepsilon_y(j)\right] - \left[\ln EE_i - \ln EE_j\right] \quad \text{(A7)}$$

where AC^* is the average variable cost function and (i) stands for a vector of variables evaluated for firm i. This equation indicates that differences in farm's marginal costs can be explained by differences in efficient average costs, differences in the cost elasticities, and differences in efficiency levels. All of these differences in turn can be decomposed following different strategies.

First, applying Diewert's Quadratic Identity Lemma to the *translog* variable cost function in (8), the differences in average costs in expression (A7) can be written as:

$$\begin{aligned} \ln AC^*(i) - \ln AC^*(j) = \; & \frac{1}{2}\left[\left(\varepsilon_y(i) - 1\right) + \left(\varepsilon_y(j) - 1\right)\right] \cdot \left(\ln \overline{Q}_i - \ln \overline{Q}_j\right) + \\ & \frac{1}{2}\left[\varepsilon_w(i) + \varepsilon_w(j)\right] \cdot \left(\ln w_i - \ln w_j\right) + \\ & \frac{1}{2}\left[\varepsilon_z(i) + \varepsilon_z(j)\right] \cdot \left(\ln z_i - \ln z_j\right) \end{aligned} \quad \text{(A8)}$$

where $\varepsilon_w(i)$ and $\varepsilon_z(i)$ are the elasticity of variable cost with respect to the input price and the quasi-fixed input respectively. The first term on the right-hand side of (A8) measures the contribution of changes in scale (movements along the average cost function). This term depends on returns to scale, measured as the scale elasticity minus one. Increasing (decreasing) returns to scale correspond to a negative (positive) value. Hence, an expansion in output leads to a decrease (increase) in average costs when increasing (decreasing) returns to scale exist. The second and third terms measure differences in average costs due to differences in input prices and quasi-fixed input levels respectively.

Second, the difference in the logarithm of the cost elasticities in expression (A7) cannot be decomposed using Diewert's Lemma since these terms are non-linear. Here we propose using a Malmquist-type procedure that relies on ratios of cost elasticities that are evaluated fixing different subsets of variables, that is:

$$\ln \varepsilon_y(i) - \ln \varepsilon_y(j) = \ln e_{yy}(i,j) + \ln e_{yw}(i,j) + \ln e_{yz}(i,j) \quad \text{(A9)}$$

where

$$
\begin{aligned}
\ln e_{yy}(i,j) &= \frac{1}{2}\left[\ln\left(\varepsilon_y(\overline{Q}_i,w_i,z_i)/\varepsilon_y(\overline{Q}_j,w_i,z_i)\right)+\ln\left(\varepsilon_y(\overline{Q}_i,w_j,z_j)/\varepsilon_y(\overline{Q}_j,w_j,z_j)\right)\right]\\
\ln e_{yw}(i,j) &= \frac{1}{2}\left[\ln\left(\varepsilon_y(\overline{Q}_i,w_i,z_i)/\varepsilon_y(\overline{Q}_i,w_j,z_i)\right)+\ln\left(\varepsilon_y(\overline{Q}_j,w_i,z_j)/\varepsilon_y(\overline{Q}_j,w_j,z_j)\right)\right]\\
\ln e_{yw}(i,j) &= \frac{1}{2}\left[\ln\left(\varepsilon_y(\overline{Q}_i,w_i,z_i)/\varepsilon_y(\overline{Q}_i,w_i,z_j)\right)+\ln\left(\varepsilon_y(\overline{Q}_j,w_j,z_i)/\varepsilon_y(\overline{Q}_j,w_j,z_j)\right)\right]
\end{aligned}
$$

The three terms on the right-hand side of (A9) measure changes in marginal costs due to changes in output levels, input prices and quasi-fixed inputs respectively, not accounted for by the average cost change term in equation (A8). These terms can be interpreted as the logarithm of the geometric mean of the differences in the cost elasticity evaluated using firm *i* and *j* data.

Finally, inserting (A8) and (A9) into (A7) and the resulting expression into (A5) yields equation (10) in the text:

Table 1. Effects of quotas on the Spanish milk sector

	1993/94	1998/99
Total quota (1000 metric tons)	5567	5567
Dairy farms	135000	71000
Dairy cows (1000s)	1379	1100
Average quota per farm (litres)	41200	78400
Average herd size	10.2	15.5

Table 2. Productive characteristics: average values for 71 dairy farms

	1993	1994	1995	1996	1997	1998
Quota (litres)	106187	111062	115803	116819	119784	121438
Milk cows	20.60	21.68	21.68	23.39	22.63	23.15
Land (hectares)	13.35	13.56	13.52	13.37	13.57	13.54
Stocking rate (cows/ha.)	1.69	1.74	1.74	1.90	1.79	1.83
Milk/cow (litres)	5300	5470	5636	5761	5750	5834

Table 3. ML Parameter Estimates of the Variable Cost Frontier

Variables	Parameters	Estimates	t-ratio
lny	β_y	1.1351	33.677
lnz	β_z	-0.1522	-4.067
lnw	β_w	0.2843	2.402
0.5(lny)^2	β_{yy}	0.1548	1.63
0.5(lnz)^2	β_{zz}	0.2161	1.16
0.5(lnw)^2	β_{ww}	0.6682	0.546
lny·lnz	β_{yz}	-0.1222	-1.657
lny·lnw	β_{yw}	0.0797	0.352
lnz·lnw	β_{zw}	-0.0055	-0.015
D94	β_{94}	0.0686	2.468
D95	β_{95}	0.0613	1.898
D96	β_{96}	0.1443	3.922
D97	β_{97}	0.1254	3.195
D98	β_{98}	0.1634	3.64
Intercept	β_0	14.3434	311.451
time trend	δ_1	-0.0644	-2.099
lnx$_2$	δ_2	-0.4758	-2.192
	$\sigma^2=\sigma_v^2+\sigma_u^2$	0.1086	3.101
	$\lambda=\sigma_u/\sigma_v$	2.4573	5.3220
Observations = 426			
Likelihood function value = 205.73			

Table 4. Efficiency, price, marginal cost and quota value

Year	Econ. Efficiency (EE)	Output price (P)	Marginal cost (MC)	Quota value (λ)
93	77.04	42.04	27.33	14.71
94	78.49	45.04	29.08	15.96
95	79.80	44.12	28.70	15.42
96	81.71	42.79	30.37	12.42
97	82.07	42.04	29.45	12.60
98	83.34	42.63	29.48	13.15

Note: output prices, marginal costs and quota values expressed in 1993 pesetas

Table 5. Decomposition of the cross-sectional differences in quota values

Year	$\hat{\lambda}-\hat{\lambda}^*$	Quota value decomposition (1)				
		OPE	EFE	SCE	QFE	IPE
93	-6.64	-0.43	-4.44	-2.37	0.59	0.01
94	-5.75	0.73	-4.38	-2.76	0.68	-0.03
95	-5.07	1.32	-3.98	-2.88	0.59	-0.13
96	-6.23	0.36	-3.79	-3.13	0.69	-0.36
97	-7.24	-0.94	-3.63	-3.02	0.72	-0.37
98	-6.43	0.28	-3.21	-2.64	-0.16	-0.70
93-98	-6.23	0.22	-3.91	-2.80	0.52	-0.26

(1) OPE=output price effect; EFE=efficiency effect; SCE=scale effect; QFE=quasi-fixed input effect; IPE=input price effect.

Table 6. Decomposing efficiency differences

Year	dlnEE	$\delta_1\ dx_1$	$\delta_2\ dx_2$	du/u
93	-0.25	0.00	-0.17	10.54
94	-0.23	0.00	-0.18	10.54
95	-0.21	0.00	-0.19	10.54
96	-0.19	0.00	-0.20	10.54
97	-0.18	0.00	-0.20	10.54
98	-0.17	0.00	-0.29	10.54

Table 7. Results of the simulation of quota allocation by the market (litres)

		Current quota	Optimal quota	%Change
Efficiency	Above average	4581321	5512400	20.32
	Below average	3644187	2713107	-25.55
Current quota	Above average	4810890	4521719	-6.01
	Below average	3414618	3703788	8.47
Land	Above average	4247206	4718729	11.10
	Below average	3978302	3506778	-11.85
Milk Price	Above average	5756315	6592989	14.53
	Below average	2469193	1632518	-33.88

Figure 1. Quota value decomposition