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The Failure of Marketable Permit Systems and Uncertainty of Environmental Policy: A Switching Regime Model Applied to the Dutch Phosphate Quota Program

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Abstract

A well-known feature of pollution control with tradable quota rights is that the benefits to ownership will capitalize into prices of the quota. Quota present a unique opportunity to examine the effect of risks introduced by governmental programs because all the return to quota is dependent upon these programs. The uncertainty of future regulatory action results from the probability that the stream of incomes could be reduced (portfolio risk) by policy variation or stopped (default risk) by a substantial switch or shock in policy regime. Eliminating the quota program is the extreme case of default risk, as it would terminate the quota benefits.

The paper concentrates on the paradox that environmental regulation can provoke economic and environmental inefficiencies because of policy uncertainty. The theory on investment under uncertainty argues that when future returns are uncertain, an opportunity to wait and see has some (quasi) option value. Under uncertainty, investments and disinvestments will take place at respectively higher and lower levels of returns creating an inaction interval. This interval means that returns to quota can vary over a wide range before trade takes place and offers a new, theoretical explanation for the failure of marketable permit systems.

The objectives of this paper are threefold. First, the option value theory is employed to forge a natural connection between political uncertainty and quota price volatility. Second, based on the option value theory, a switching regime model is developed for investing and disinvesting in quota. Third, the empirical evidence for the Dutch Phosphate Quota Program indicates that policy risks led to asset fixity. Consequently, the market of tradable phosphate quota was not effective with major negative implications for both economic and environmental efficiency.

Keywords: switching regime, option theory, policy risk, asset fixity, phosphate quota, pork production.

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1. Introduction

A well-known feature of pollution control with tradable quota rights is that the benefits to ownership will capitalize into prices of the quota. Capitalization of program benefits reflects expectations about future policy. Therefore, the value of policy created assets reflects farmers' assessment of the level, variability and duration of future returns to policy (Sumner and Wilson, 1998). Quota present a unique opportunity to examine the effect of risks introduced by governmental programs directly because all the return to quota is dependent upon these programs. The uncertainty of future regulatory action results from the risk that the stream of incomes could be reduced or stopped by a change in policy regime. It is useful to distinguish to types of risk. "Portfolio risk" refers to the effect of perceived policy variation whereas 'default risk' refers to the probability of a substantial switch or shock in policy regime (Barichello, 1996). Eliminating the quota program is the extreme case of default risk, as it would terminate the quota benefits.

Two related strands of micro-economic literature recognize the possible micro economic effects of political uncertainty: studies of capital asset price volatility and recent work on investment under uncertainty. Barichello (1996) and Sumner and Wilson (1998) investigated rates of discounts and rates of return for dairy quota in Canada and the US using insights from the capital asset pricing model (Black and Scholes, 1973). They found the price of the dairy quota to be well below the expected capitalized value, indicating high risk premiums for policy uncertainty. Similar results have been reported for tradable quota in other agricultural commodities such as broilers and eggs, tobacco, and peanuts (Lerner and Stanbury, 1985; Rucker and Thurman, 1990; Sumner, 1988). High discount values are also found for quota of non-agricultural commodities such as textiles (Barichello, 1996).

The theory on investment under uncertainty argues that when future returns are uncertain, an opportunity to wait and see has some (quasi) option value[i] (Dixit and Pindyck, 1994). Under uncertainty, investments and disinvestments will take place at respectively higher and lower levels of returns creating an inaction interval. Recently this inaction interval has been put forward as an alternative explanation for hysteresis or asset fixity. Richards (1996) was the first to empirically confirm hysteresis in quota investments for the case of Canadian dairy farming. This study also showed that the hysteresis indirectly causes slow adjustment in other inputs resulting in economic inefficiency. These negative indirect effects of quota fixity are reported also in the literature on structural developments in agriculture (*e.g.*, Burrell, 1989; Rucker *et al.*, 1995; Boots *et al.*, 1997).

This paper addresses the system of manure production rights in The Netherlands. Dutch legislation allows a total manure production from all animal sources of up to 125 kg of phosphate (P_2O_5) per hectare of land. Farmers producing more manure in terms of phosphate need additional quota. This case is used to make three contributions to the literature. First, the option value theory is employed to forge a natural connection between political uncertainty and quota price volatility. Second, the analysis shows light on the further tightening of environmental regulations in the context of a quota system

and specifically on the way this was formalized for Dutch animal agriculture. Third, the empirical results indicate that policy risks led to hysteresis. Consequently, the market for tradable phosphate quota was not effective with major negative implications for both economic and environmental efficiency. Similar failures of marketable permit programs have been observed elsewhere, most notably with the five nutrient trading programs in the U.S. where no trades were made at all (Hoag and Hughes-Popp, 1997).

The next section reviews the Dutch phosphate quota program. The third section provides a new, theoretical explanation for the failure of marketable permits and sections four and five presents an application to the Dutch phosphate program. Section six concludes with the policy implications and offers some final remarks.

2. An Overview of the Dutch Phosphate Quota Program[ii]

The system of manure production rights (manure quota) in The Netherlands was introduced in two steps: in 1987 for the production of manure from cattle, swine and poultry, and in 1992 for the production of manure from sheep, goats, ducks, foxes, nutria and rabbits. Each farm was ascribed a "reference amount" based on the inventory of animals and standards for the manure production for each specific animal category measured in kilograms of P_2O_5 per year[iii]. On Dec. 31, 1986 (and again on Dec. 31, 1991), all land either owned or long term leased (minimal 6 years and officially registered) used for agricultural purposes was assessed. The difference between the reference amount and the assessed acreage based phosphate rights was used to establish a distinction between manure surplus farms (with manure production in excess of 125 Kg of P_2O_5 per hectare) and manure deficit farms (with phosphate production below 125 Kg/ha). A deficit farm can still increase animal production on the basis of unused land based manure production rights. For a manure surplus farm such an increase in production capacity is only possible with an increase in the reference quantity of manure production rights.

Trading rules

The regulation indirectly caused a moratorium hampering the adaptation and investment processes required for resolving the national manure problem. To counteract these limitations part of the production rights became tradable by January 1, 1994. For each farm the reference amount was converted into "manure production rights" (manure quota) to indicate the change in policy. In contrast to the homogeneous reference amount, manure production rights became highly differentiated to restrict the trading. This was done in three steps.

First, a farm's total manure quota was officially divided into two parts: land based part and non-land based part. The first part amounts to 125 kg of P_2O_5 times the number of hectares of land on the farm, whereas the non-land based part is calculated as the difference between a farm's reference amount and the land based quota. Second, each farm's non-land based quota was allocated to specific animal categories (cattle & turkeys, pigs & chickens, others) reflecting the situation on the specific farm[iv]. The non-land-based quota became tradable with trading being restricted across the three animal

categories. Third, trading of the animals-based phosphate quota is also geographically restricted to keep the animal population from further increasing in the concentration areas. Transferring quota is allowed within regions and from a manure surplus region into a deficit region, but prohibited from a manure deficit region into a manure surplus region. There are two manure-surplus regions[v]: The East with the province of Gelderland and a large part of Overijssel and The South with the province of Noord-Brabant and a small part of Limburg (Figure 1). Finally, there is a 25% reduction in quota when the transferable animal based quota is actually sold to curb the national manure surplus. This reduction applies to all animal categories.

As before there is still a distinction in manure surplus and manure deficit farms. If a manure surplus farm acquires additional land, the land-based quota that goes with it automatically 'sinks' into the animals based quota. So, for a surplus farm, acquiring more land reduces the tradable part of the quota by increasing the land-related share and reducing the non land-related share. This implies that the purchasing of animal based quota is the only way to increase production capacity for a surplus farm[vi].

Policy uncertainty

The future of the quota system was uncertain from the beginning because of expected changes in policy. In 1993 the central agreement between the Ministries of Agriculture and the Environment and the farmers' union (Landbouwschap) was that by 1998 the quota system would become obsolete[vii] with the introduction of a nutrient accounting scheme at the farm level (Breembroek *et al*., 1996). The scheme included strict nutrient application standards for phosphate and nitrogen per hectare and a prohibitive tax on any surpluses. With such a scheme a farm's legal production capacity would not be determined by the amount of quota but by its capacity of manure disposal, either by land application on the own farm or by hauling it to a crop farm in the deficit region. The scenario was met by massive protest from farmers, forcing union leaders to distance themselves publicly from the plan (Frouws, 1997). Besides, the plan was met with serious doubts on the part of the environmental organizations and drinking water suppliers[viii].

In October 1995, the definitive governmental proposal was launched. Nutrient accounting would become obligatory for both phosphate and for nitrogen. Nutrient surpluses above the waste standard would be subject to a high tax to ensure manure disposal to the deficit regions. Added to the political agenda by mid July 1997 was a 25 percent reduction in animal numbers specifically for the swine sector. Note that the latter is identical to a cut in swine quota. Competing farmer action groups (including a radical union of pig farmers, Nederlandse Vakbond Varkenshouders or NVV) voiced their protest and attacked with renewed vigor eager to gain time. Eventually, on January 1, 1998 the nutrient scheme was enacted but without abolishing the quota system. Instead the quota systems was further detailed by separating the swine quota from those for chickens and broilers as of September 1, 1998. A general 10 percent reduction in swine quota by farm became effective by the same date. This reduction was part of the Pig Farming Restructuring Act (Wet Herstructurering Varkenshouderij), aimed at reducing the generated manure and the pig herd by 25% by the year 2000 (with 1995/1996 as base year). The act also included stricter health and veterinary requirements for the pig

production industry. Originally the Act passed the legislative hurdle. However, it became subject to litigation between the NVV and the Dutch government and, therefore, halted until January 2000. On January 20, 2000, the Court in The Hague declared the 10% reduction in the size of the pig herd as enacted on September 1, 1998 legitimate. However, the court decision exempted the second generic reduction by 15% that was announced for 2000.

Even though quota became tradable by January 1994, trade was not observed until spring of 1996 and the number of transactions has been limited in relation to the number of farmers involved (about 12000).

3. A Conceptual Model

To interpret the policy setting we limit our analysis to the surplus regions, *i.e.* we assume that all farms are surplus farms and that increasing production capacity can only be achieved by buying animals based quota from another farmer within the same surplus region.

Let there be two types of producers in the sense that they have identical amounts of quota, M, but different technical opportunities (Figure 2). The firms' marginal cost curves, MC_1 and MC_2 are held to be increasing and convex in output. Assuming that the market price of the output, P, exceeds the marginal cost of production, possession of quota is valuable. The value of the marginal product of quota is the difference between the price of the output and marginal costs. The difference in marginal cost between the two farmers implies that the fixed amount of output as associated with quota $M_T = M_1 + M_2$ is not produced at minimum cost.

Introducing trade implies producers with low cost of production will buy or lease quota from producers with higher cost. From Figure 2 it can be seen that in equilibrium an amount of ΔM units of quota will be transferred from farmer 2 to farmer 1. The observed market clearing lease rate will be equal to $A_T P^*$ which is the difference between the expected market price and the marginal costs of production MC_T. Both the high cost and the low cost producer will have an increase in producer surplus. Figure 2 also gives the intuition to the impact of a general reduction in quota. Assuming that the marginal costs curves remain unchanged, a shift of the $M_1 = M_2$ limit to the left would lead to higher quota rental rates.

From the discussion above it follows that a system of tradable production quota is of major benefit to *both* sellers and buyers compared to quota as a strict limit to production. In the Dutch phosphate quota system users of quota are all owners of quota In that situation, farmers in general will be in favor of the tradable quota system to stay in place — they would all suffer a loss in asset values with phasing out of the system.

The Dutch phosphate quota system does not allow leasing — quota can only be acquired by purchase and the trade is open to farmers only. The classical NPV rule implies that investment in quota is profitable when the differential between the discounted expected future returns (capturing variability in output price P and MC) and the quota price is at least equal to the irreversible entry cost, *i.e.* the transaction costs of

acquiring quota. The differential however is uncertain as it is affected by the uncertainty of future environmental policy. Stricter rules on animal waste disposal or the introduction of a pollution tax would lead to an upward shift in MC, lower returns to quota and a reduction in the volume of trade. The phasing out of the quota program would make the quota valueless and would lead to complete inaction on the quota market.

Let R denote the differential between the discounted future returns and the quota price and let k denote transaction costs of acquiring quota. It is optimal to buy quota as long as $R > k$. To account for uncertainty, we assume the differential, R, follows a geometric Brownian motion. Further we allow for the possibility that, at some random point in time, R may take a Poisson jump because of a change in the policy system. So, the asset return equation is[ix]:

$$dR = \mu R dt + \sigma R dz - R dq \qquad (1)$$

where μ, σ and dz are the mean growth rate, the standard deviation and the increment of the Brownian process; dq denotes the increment of the Poisson process, and dz and dq are independent. Equation *(1)* implies that current returns to quota ownership are known but future values are lognormally distributed and that at each point in time there is a small chance of a change in q affecting the original return. After this, the returns continue fluctuating as before until another event happens. Notice that this includes the possibility of the shift being permanent.

To interpret equation *(1)*, let the Poisson jump take the form of a drop in returns denoted by a fixed percentage θ of R and its probability by λ, that is $-Rdq = -\lambda dt\theta R$. The expected rate of change of R now is not μ but instead is $(1/dt)\ E(dR)/R = \mu - \lambda\theta$. Thus the policy risk reduces the expected rate of change of R and it also contributes to the variance of the rate of change of R.

Applying Ito's lemma to R provides an expression for the expected gain from owning quota over time, E $\{dF(R)\}$:

$$E\{dF(R)\} = \mu R\ F'(R)dt + \frac{1}{2}\sigma^2 R^2 F''(R)dt - \lambda\ \{F(R) - F[(1-\theta)R]\}dt \qquad (2)$$

where the higher order terms of the Taylor series expansion are ignored and primes denote derivatives, *i.e.* $F'(R) = dF(R)/dR$. Dividing the expression in *(2)* by dt, and setting it equal to the normal net returns to quota investment, provides the arbitrage condition for continuing to wait and see or to invest in (additional) quota (Pindyck and Dixit, 171):

$$\mu R F_b'(R) + \frac{1}{2}\sigma^2 R^2 F_b''(R) - \lambda\ \{F_b(R) - F_b[(1-\theta)R]\} - rF_b(R) = R \qquad (3)$$

where $F_b(R)$ is the value of the investment opportunity. The equilibrium condition for a producer to continue to use quota or to sell it differs in the sign of the per period dividend:

$$\mu R F_S'(R) + \frac{1}{2}\sigma^2 R^2 F_S''(R) - \lambda \ \{F_S(R) - F_S[(1-\theta)R]\} - r \ F_S(R) = -R \qquad (4)$$

where F_s *(R)* is the value of the opportunity to sell. The solutions to the arbitrage equations *(3)* and *(4)* take the form (Dixit, 1989: 626-627):

$$F_b(R) = A\,R^{\alpha} - R/(r-\mu) \quad , \quad F_S(R) = B\ R^{-\beta} + R/(r-\mu) \qquad (5)$$

where *A* and *B* are constants. The optimal solution for *A* and *B* requires that at the margin of investing and disinvesting the earnings must be equal after deducting the entry or exit cost (value matching condition):

$$F_b(R_H) = AR_H^{\alpha} - R_H/(r-\mu) = BR_H^{-\beta} + R_H/(r-\mu) - k \qquad (6a)$$

$$F_S(R_L) = BR_L^{-\beta} + R_L/(r-\mu) = AR_L^{\alpha} - R_L/(r-\mu) - m \qquad (6b)$$

where *k* denotes the entry cost as before; *m* denotes the exit costs, and R_H and R_L are the investment and disinvestment trigger, respectively. In addition the smooth pasting condition requires that at the margin the increments in earnings are identical:

$$F_b'(R_H) = \alpha A\ R_H^{\alpha-1} - 1/(r-\mu) = -\beta B\ R_H^{-\beta-1} + 1/(r-\mu) \qquad (7a)$$

$$F_S'(R_L) = -\beta B\ R_L^{-\beta-1} + 1/(r-\mu) = \alpha A\ R_L^{\alpha-1} - 1/(r-\mu) \qquad (7b)$$

To simplify these non-linear equations we recall that the literature generally concludes that trade in marketable permits is limited, *i.e.* that *R* is small. In that case the probability of *R* rising to a level inducing investment is very low and we can assume A = *0* (*cf.* Richards and Patterson, 1998: p.686). Under this assumption equations *(6)* and *(7)* imply:

$$-\beta B\ R_H^{-\beta-1} = \frac{-2}{r-\mu} \quad , \quad BR_H^{-\beta} = \frac{2R_H}{r-\mu} - k \qquad (8)$$

The triggers for investment and disinvestment in quota, R_H and R_L, can now be denoted as:

$$R_H = \left(\frac{1}{2}\right)\left(\frac{\beta}{1+\beta}\right)\{k(r-\mu)\} \quad , \quad R_L = -\left(\frac{1}{2}\right)\left(\frac{\beta}{1+\beta}\right)\{m(r-\mu)\} \qquad (9)$$

Equation *(9)* demonstrates how the R_H and R_L trigger differs from the NPV triggers per period, *kr* and *-mr*. The gap is determined by the growth rate, μ, of the Brownian

process and by β. The latter is defined in terms of the diffusion-jump process in equation *(1)* and can be written as (Dixit and Pindyck, 1994: p.171):

$$\frac{1}{2}\sigma^2\beta(\beta-1)+\mu\ \ \beta-(r+\lambda)+\lambda(1-\theta)^{\beta}=0 \qquad (10)$$

If $\theta = 1$ equation *(10)* changes to:

$$\beta=\frac{1}{2}-\mu/\sigma^2\ \ +\sqrt{[\mu/\sigma^2-\frac{1}{2}]^2+2(r+\lambda)/\sigma^2} \qquad (11)$$

Equation *(10)* applies when it is unknown whether the quota system will change and also when changes may take place. Equation *(11)* describes the situation in which the change of the quota system is permanent. Both equations demonstrate that portfolio and default policy risk (change in σ and in λ respectively) have disproportional impacts on the trigger values.

The difference between the two trigger values, R_L and R_H , means that returns to quota can vary over a wide range before investment or disinvestment take place and offers an theoretical explanation for lack of trade in marketable permits. The practical relevance of the explanation is an empirical question.

Following Richards and Patterson (1998) a linear approximation was used for the option value in equation *(9)*. The market situation for quota can then be described by three conditions:

$$R=\begin{pmatrix} R_H=C(k)+O_H(\mu,\sigma,\lambda\theta) \\ R=C \\ R_L=C(m)-O_L(\mu,\sigma,\lambda\theta) \end{pmatrix} \qquad (12)$$

where C denotes the transaction cost and O_H and O_L are the option values of investing and desinvesting in quota, respectively.

Under the second regime in equation *(12)*, policy uncertain is absent and the market of quota trades is efficient. Under the first regime, the differential is more than the transaction cost which is the option value of remaining inactive. Similarly, the third regime represents the case where the differential is negative which indicates the option value of holding on to active quota in the hope of changes in policy that would increase the quota value. Notice that the option values can only be observed when the triggers are reached.

4. Empirical Model

Empirical assessment reveals which one of the three conditions given in equation *(12)* prevails and enables a verification of the impact of policy risk on quota transfer for the phosphate quota system in the Netherlands. Recall that R is the differential between the

capitalized returns to quota use and the quota price. This differential is attributed to unobservable transaction costs and option values in the quota market. Combining this definition of *R* and equation *(12)* the empirical model was specified as follows:

$$\left(\frac{W_t}{r_t}\right) - Q_t^i = C^i + O^i(\mu^i, \sigma^i, \lambda\theta^i) + \nu_t + \upsilon_t \text{, with probability } l_1 \qquad (13a)$$

$$\left(\frac{W_t}{r_t}\right) - Q_t^i = C^i - O^i(\mu^i, \sigma^i, \lambda\theta^i) + \nu_t - \upsilon_t \text{, with probability } l_2 \qquad (13b)$$

$$\left(\frac{W_t}{r_t}\right) - Q_t^i = C^i \text{, with probability } 1 - l_1 - l_2 \qquad (13c)$$

where W_t are earnings of quota use; r_t is the interest rate; Q_t^i is the observed quota price in region *i*, transaction *t*; C^i is the transaction cost of buying or selling quota; O^i is the option value of acquiring quota or selling quota; ν is a normally distributed i.i.d. variable; and υ is a half normal random variable truncated at zero from below and distributed independent of ν. The specification reflects that quota prices are determined in local markets *i* in line with the regulation that trade is only allowed within the two surplus regions and not between these regions. Returns to quota use, *W*, were not regionally differentiated. Given the size of the Netherlands (approximately 150 by 200 miles) and the well-developed infrastructure, effect of distances on farm gate prices for outputs and variable inputs is very small.

Hypothesis tests of the probabilities l_1 and l_2 constitutes an assessment of the extent of policy risks. If equation *(13c)* prevails, policy risks are of no significance. In case of equation *(13a)*, there is a positive option value. In the policy setting described above this difference is the option value of waiting and seeing what might happen with the quota program before buying quota. This situation represents a state of surplus of quota. In the case of equation *(13b)*, quota prices paid are higher than the discounted earnings minus the acquisition costs which would imply a shortage of quota.

We also considered an alternative specification alternative to *(13a)-(3c)* where a binary variable was added to the option values O_H and O_L. This variable takes a value of 1.0 beginning in July 1997 to account for the change in policy by the announcement of a 25 percent reduction in quota for each pork producer. The effect of this announcement in terms of the switching regime model is unclear. One perspective would be to consider the announcement a reduction in policy uncertainty, *i.e.* a confirmation that the quota system was to remain with higher marginal quota values in the new situation (see the discussion of Figure 2). The opposite view would be to consider the announcement as an increase in default policy risk.

To estimate the probabilities l_1 and l_2 of the two specifications for the switching regime model were chosen in order to maximize the log of the likelihood function (Sexton *et al.*, 1991; Richards and Patterson, 1998):

$$L = \prod_{t=1}^{N} [l_1 f_t^1 + l_2 f_t^2 + (1 - l_1 - l_2) f_t^3] \qquad (14)$$

where N is the total number of observations and f_t^1, f_t^2 and f_t^3 denote the density functions of *(13)*:

$$f_t^1 = \left(\frac{2}{S}\right)\phi\left(\frac{Z}{S}\right)\left[1 - \Phi\left[\frac{-Z(\sigma_\upsilon / \sigma_V)}{S}\right]\right],$$

$$(15) \quad f_t^2 = \left(\frac{2}{S}\right)\phi\left(\frac{Z}{S}\right)\left[1 - \Phi\left[\frac{Z(\sigma_\upsilon / \sigma_V)}{S}\right]\right],$$

$$f_t^3 = \frac{1}{\sigma_V}\phi\left(\frac{Z}{\sigma_V}\right)$$

where $S = \left(\sigma_\upsilon^2 + \sigma_v^2\right)^{0.5}$; $Z = \left(\frac{W_t}{r_t}\right) - Q_t^i - \left[C^i + O^i(\mu_t^i, \sigma^i, \lambda\theta_t^i)\right]$ and ϕ and Φ are the density and the cumulative density function of the standard normal variable, respectively. In the alternative specification, a variable D times a dummy was added to $C + O$ to distinguishing the period after July 1997. The parameters C, O, D, l_1, l_2, σ_υ and σ_v are estimated for each region i by maximizing the log of *(14)*.

The only data used in the estimation were quota prices, earning of quota use and the interest rate. Data for quota prices comprised a series of 166 and 103 individual transactions in quota for swine in the region south and east, respectively. These series cover the 26-month period April 1996-May 1998. Earnings were measured by the returns to labor in guilders per pig place in finishing swine production. Returns to labor was chosen instead of the net returns to take account of the inelastic labor supply in Dutch agriculture. This information is available on a monthly basis (J.H. Wisman, personal communication, LEI-DLO, 1998). Because of the considerable delivery lags of quota use, returns W_t were based upon expected future earnings instead of current earnings. In the estimation, the average returns to labor over the last 12 months was used as a rational expectation of these future earnings. Finally, the returns per pig place had to be reformulated per unit of quota. To increase the production capacity by one pig place, 7.4 kg of phosphate quota are required. When quota is acquired only 75% can actually be used (see section 2). So, to construct the data for W_t the 12-month averages of the return to labor were divided by 9.87 (= 7.4*4/3). In addition monthly data were used on interest rates for r. Table 1 provides summary statistics for quota prices, earning of quota use and the interest rate.

5. Results

The estimation was conducted using the NLPNRA (Newton-Raphson method) and the NLPFDD routines in SAS/IML version 7.0. The latter routine enables the variance of

the parameters to be estimated by the evaluation of the Hessian at the maximum likelihood estimates (Green, 1993: 115). Table 2 shows the model estimates both for the two-region average and for the regional markets separately.

Estimates of the average phosphate quota model (model 1) for the pooled data support the evidence of inaction on the quota market. Market equilibrium is absent and the option value of 91.80 implies that the trigger to invest in quota is significantly over the NPV trigger estimated here to be 8.85. Relaxing the assumption that the option values are constant for both surplus regions permits an assessment of differences in efficiency of the quota market for the two regions. It may be that the market in one of the two regions particularly caused the overall inefficiency. The sets of regional estimates bear this out. The probability of a wait and see attitude is considerably higher larger for the region East where the estimated option value is also much higher.

Model 1 is subject to rather restrictive assumption regarding the option value even when estimated for the two regions separately. In particular, it is assumed that the option values are constant over the entire range of the data. Model 2 includes an additional variable to test for the impact of default policy risk, *i.e*. the risk of a general cut in quota at some future date. The announcement of a policy plan including such a future cut in July 1997 let to significantly higher option values and less efficient markets. These results are consistent with the effects of a Poisson jump. Notice that the policy announcement particularly affected the quota market in the south.

6. Discussion and Conclusions

Based on the option value theory this paper has developed a switching regime model for the market of tradable permits. The model enables an evaluation of the market inefficiency caused by both expected changes in policy and a potential (partial) termination of the permit system. The threshold model was applied to phosphate quota for pork production in The Netherlands. The results strongly suggest that this market is characterized by threshold behavior. The estimated option value was estimated as positive which indicates a wait and see attitude regarding investment. There were considerable differences in the estimated probabilities of the two threshold regimes between regional markets. In all cases equilibrium on the quota markets was estimated to be virtually absent. In most cases a surplus of quota was observed. The announcement of a policy change in mid July 1997 was found to have further disturbed the market, particularly in the southern region.

Inaction on the Dutch phosphate quota markets prohibited the automatic reduction in animal numbers and associated manure that would have been generated by quota trade (because of the 75 % rule). Moreover, the hysteresis led to less environmental improvement. With trade, the farmer who acquires quota has to certify that he has either sufficient land on his own farm to dispose off the total manure for the next two years or has a manure disposal contract with another (crop) farm.

The empirical evidence shows that the uncertainty generated by the process of a decision on alternative policies can be a serious deterrent to investment in marketable permits. Consequently, policy uncertainty incurs aggregate welfare losses because of

misallocation of resources to produce the permitted output. For the specific case analyzed in this paper a system of leasing could be considered as an alternative to a system that only allows transfer through purchase. Leasing can be expected to increase the mobility of quota.

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Figure 1 Livestock concentration areas in the Netherlands

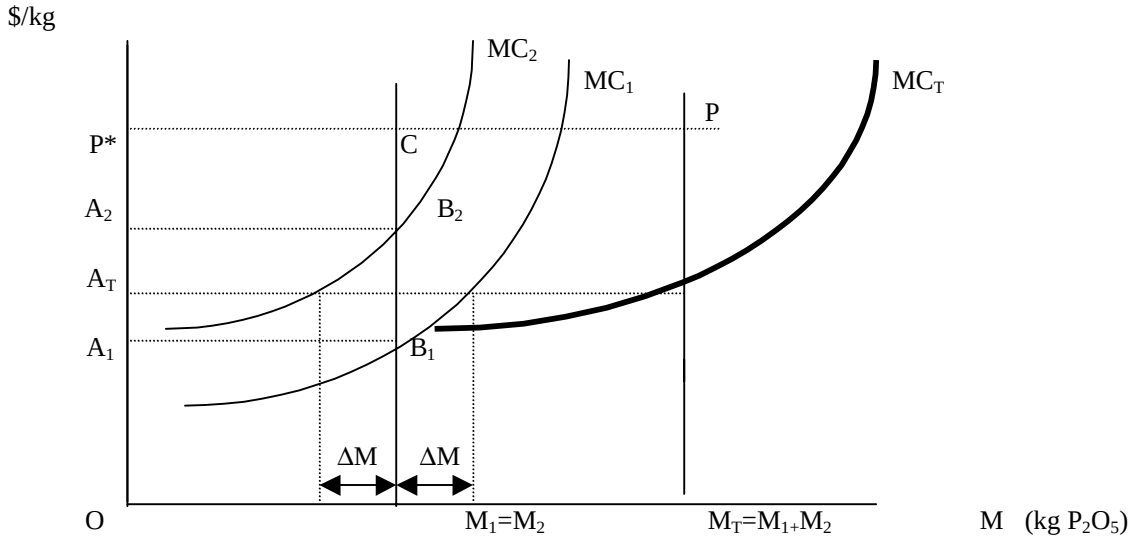

Figure 2 Marginal cost of production and the effects of quota trade

Table 1 Summary statistics of the data used in the estimation of the Dutch Phosphate Quota Model: April 1996-May 1998.*

Variable	Mean	Minimum	Maximum	Standard Deviation
Quota price South (NLG per kg P_2O_5)	66.11	29	100	15.99
Quota Price East (NLG per kg P_2O_5)	48.69	20	80	18.33
Interest (%)	5.31	6.04	4.76	0.37
Annual returns to labor (NLG/pig place)**	84.92	36	129	29.80

* Monetary values in Dfl (1 Dfl = 0.5 US$).
** Average last 12 months.

Table 2 Parameter estimates for the Dutch Phosphate Quota Model: Average and by region for two specifications, April 1996-May 1998.

Variable[a]	Average		Surplus Region South		Surplus Region East	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
C	8.85 (0.26)[b]	1.73 (0.13)	2.37 (0.03)	2.46* (1.99)	3.89 (0.03)	8.46* (23.19)
O	91.80* (2.99)	84.73* (4.72)	77.54 (0.90)	71.31* (20.75)	188.76 (1.39)	152.57* (418.21)
D		74.77* (11.52)		68.10* (6.37)		39.17* (169.23)
σ_v^2	1634.75 (0.26)	488.62 (0.32)	2.75 (0.03)	0.04 (0.02)	52.15 (1.67)	156.40 (0.37)
σ_υ^2	951.91 (0.15)	1255.20 (0.79)	1937.46* (8.21)	1559.19* (9.11)	5661.92* (7.40)	3186.99 (0.15)
l_1	0.52* (2.58)	0.54* (5.18)	0.58* (9.85)	0.65* (10.39)	1.00 [c]	1.00 [c]
l_2	0.48* (2.36)	0.46* (4.36)	0.41* (8.31)	0.35* (7.61)	0.00 [c]	0.00 [c]
Log likelihood	-1438.56	-1382.19	-861.52	-838.11	-508.88	-527.57
Observations	269	269	166	166	103	103
O as % of mean discounted net returns	57	52	48	44	116	94
D as % of mean discounted net returns		46		42		24

[a] The variable definitions are *C* = the transaction cost of buying or selling quota; *O* = is the option value of either acquiring or selling quota; *D* = policy change dummy July 1997-May 1998; σ_v^2 = variance of ν error term; σ_υ^2 = variance of υ error term.
[*] Significant at the 5 % level (two sided).
[b] t-statistics in parenthesis.
[c] Constrained to the [0,1] interval in the estimation.

Endnotes

[i] Notice that this is another form of option value than that existing in the financial literature. In finance, an option represents the right, but not the obligation to buy or sell a stock on or before a given future expiration date (American option) or at a given time prior to this expiration date (European option).

[ii] A more detailed overview is given in Vukina and Wossink (2000).

[iii] These standards were calculated as the difference between phosphate supply (in feed, animals, fertilizer etc.) and phosphate removal (in meat, milk, eggs, animals, etc.). The residual is assumed to represent the phosphate content in manure. For the assessment of the number of animals different dates were used: December 31, 1986 for pigs, poultry and cattle, and December 1991 for sheep, goats, rabbits, ducks, foxes and nutria (Amvb Registratiebesluit dierlijke meststoffen Stb. 625, 1986).

[iv] Using the inventory figures on animals from earlier assessments of the reference amount, each farm's total manure quota (divided into the land-based part and the non land-based part) was partitioned into animal categories. This was accomplished by using a ranking scheme reflecting the extent to which keeping various categories of animals is truly land related. Three classes were established: (1) cattle and turkeys, (2) sheep, goats, foxes, nutria and ducks, and (3) pigs, chickens or broilers. In the Netherlands, hog, broiler and other small animal farms are confined animal husbandry operations, while cattle farms are generally not, and hence cattle farming is more directly land related. As the result of this regulation, larger part of the non-land based (tradable) quota became allocated to pigs & chickens/broilers (Vukina and Wossink, 2000).

[v] In the surplus regions average manure production is more than 125 kg P_2O_5 per hectare. With average manure production below the 125 kg of P_2O_5/ha threshold, the remaining part of the country is considered a manure-deficit region.

[vi] As an example, consider a 3-hectare farm with 1,000 finishing pigs. The animal specific transfer coefficient for finishing pigs is 7.4 Kg of P2O5 per animal per year. Therefore, this farm's total reference amount is 7,400 Kg of phosphate per year. Given that the land based phosphate allowance is 125 Kg of P_2O_5 per hectare, the total reference amount is composed of $3 \times 125 = 375$ Kg of land based quota and $7{,}400 - 375 = 7{,}025$ Kg of animals based quota. Buying 1 hectare of additional land, would increase the land based quota to 500 Kg but would at the same time decrease the animal based quota to 6,900 Kg without changing the total available quota. Consequently, this farm would have to buy additional 55.2 hectares ($55.2 \times 125 = 6{,}900$) of land before the total quota available for production would go up.

[vii] Art. 22-3 of the "Law regulating transfer of manure production rights" even states that the quota system will be terminated January 1, 1997.

[viii] This was due to a debate whether the nutrient accounting/prohibitive tax system indeed would be capable of reducing the national manure surplus. Also additional research on the auditability of the scheme was requested as it was expected to be susceptible to fraud.

[ix] The derivations follow Dixit (1989) and Dixit and Pindyck (1994: 167-172) were greater detail is provided.