Tradable Substitution Rights: Simulation of the Cost-Efficiency of a Nitrogen Reduction in the Pig Finishing Sector

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Abstract

To comply with the European Nitrate Directive, the Flemish manure policy has been elaborated mainly on the base of command and control measures (maximum fertilisation limits etc.). In literature, however, tradable permits are described as a cost efficient and effective instrument. Applied to nutrient emission they might offer an alternative for the current, expensive manure policy. In this publication both policy instruments are compared by means of simulation models. Based on accountacy data from 190 pig finishing farms, it is shown that tradable rights may result in cost savings of over 88 %, compared to the most cost efficient command and control model. This result indicates that tradable permits at least need to be considered as a plausible policy instrument for the agricultural sector.

Keywords:

Tradable Permits, Agriculture, Command and Control, Nitrogen, Linear Programming

JEL

C61: Optimization Techniques; Programming Models; Dynamic Analysis

D23: Property Rights

H23: Externalities; Redistributive Effects; Environmental Taxes and Subsidies

Q58: Environmental Economics: Government Policy

Q52: Pollution Control Costs; Distributional Effects (Firm Behavior)

1 Introduction

European and Flemish legislation aim at the reduction of nitrogen pollution from agriculture. This legislation unfortunately lays a burden upon the Flemish agricultural sector and has led to financial and even social tragedies in some agricultural households. This is mainly due to the predominance of command and control (CAC) instruments in this legislation and to the lesser attention to other policy instruments that (may) result in an environmental and socio-economic win-win situation.

The slow and expensive process of the nitrogen pollution reduction from agriculture is the result of the legislator's urge to command and control all aspects of the manure cycle. This resulted in production, recycling and treatment standards. Unfortunately, the necessary mechanisms to induce efficiency improvements were not introduced properly. This makes the urge for a more simple, transparent and cost-effective policy more imminent. To fulfil these high expectations, the legislator should introduce a maximum regional nitrogen production level instead of a maximum farm production level. Moreover, incentives should be given to reduce nitrogen production per animal while allowing farmers to make a choice how to reduce the abundant nitrogen production: reduction in animals, efficiency improvement, or manure treatment. One policy instrument manages to cope with all these conditions and will therefore be the subject of this paper: tradable permits.

However, a possible change to more efficient policy measures faces strong opposition from the main stakeholders, in particular from farmers' unions. The deep- rooted anxiety for extra costs still remains their main motive for opposition, despite the fact that tradable permits theoretically offer cost-effective solutions. This incomplete knowledge is the main factor of institutional inertia (see Eggertsson, 2004, for a similar diagnosis of initial obstructions to fish quota). The question arises whether more concrete insights in potential gains would incite more efficient policy arrangements. This paper therefore aims at exploring the economic potential of a tradable permit system as an instrument of nitrate policy.

The paper is organised as follows. The first section comprises this introduction. The next section describes the Command-and-Control and the Tradable Substitution Rights model and gives a brief overview of the data used in the different models. The third section consists of three parts. The outcome of the first model is dealt with in the first part. In the second part the results for the tradable rights model are more thoroughly discussed: (1) a supply and demand curve for substitution rights are deduced from the results, (2) market players are looked at individually (3) excretion efficiency improvements are calculated and documented and finally (4) a sensitivity analysis is performed. In the third part the outcome of the Tradable Substitution Rights model is compared in detail with the outcome of the least cost scenario from the Command-and-Control model. The fourth and last section draws a conclusion in particular with respect to further policy-making.

2 Data and methodology

2.1 Introduction

Trying to reduce nutrient pollution, the Flemish government focuses on three aspects. First of all the government uses manure recycling limits to reduce the recycled nutrient quantity. By putting a limited recycling capacity on each acre of land, the government introduced a recycling right. Secondly, the government want to reduce the production of nutrients. By using forfeit excretion coefficients for each type of animal and historical references of numbers of animals, dating back from the mid nineties, the legislator introduced a farm- based and farm-bounded production limit (the so called *nutriëntenhalte* or NH). Through the reduction of the forfeit excretion coefficient (the so called *nutriëntcoëfficiënt* or NHc) the individual farmers are forced to reduce their farm-based nutrient production. Moreover, no rise of the number of animals is allowed, even if a lower real excretion coefficient than the forfeit one is achieved. In fact, the NH resulted in production rights of nutrients. Third aspect is that stringent manure treatment obligations were laid down upon those farms with a land-decoupled production, e.g. the pig finishing sector. The government has high expectations on the feasibility of manure treatment. Unfortunately, the necessary investments do not follow until today. Changing ownership of the above-mentioned rights is only allowed under certain conditions. E.g. when taking over another farm, 25 % is cut of the total package of nutrient production rights.

Moreover, the nutrient production realised under the other 75 % must be delivered to manure treatment installations, even when sufficient hectares are available for recycling the nutrients (e.g. acquired with the take-over).

One may say that despite the CAC-orientation of this legislation, already parts of a mature tradable permit system exist but are not accepted as such. Therefore the purpose of this investigation is pointing out these hidden elements and offering a framework leading to a better acceptance of this policy instrument, especially in the agricultural sector.

Besides the well-known cost reducing effect, tradable permits generate other advantages, amongst others: certainty of realising the environmental goal; no knowledge is needed about the individual marginal abatement cost (MAC) curve; no in-between adaptation needed for inflation, economic growth or technological progress, lower control costs for the government (Baumol and Oates, 1988; Hahn, 1989; Hanley *et al*., 1997; Montero, 1997; Requate, 1998; Barde, 2000).

The success of introducing a tradable permit system depends on some key factors. Therefore such a system cannot be introduced at random. Amongst others Hanley *et al.* (1997), Barde (2000), Hussein (2000) and Löfgren (2000) prefer introduction when:

- the individual MAC differ sufficiently amongst the different actors;
- sufficient market players are found to guarantee a continuing trade in rights;
- the possibility to reduce individual reduction costs;
- the subject of the rights is properly identifiable and measurable;
- the producers are convinced of the benefits the tradability has to offer them.

The same authors finally give some guidelines for the introduction of a tradable permit system:

- guarantee low transaction costs;
- leave no room for doubt how the initial distribution of rights will be carried out;
- construct a legal framework and make the trade as free as possible;
- keep the market rules transparent and simple;
- create a good control mechanism and see to it that violators get a fine higher than the price of a right.

The more market players in a system of tradable permits, the more the transaction costs will reduce (Noll, 1982; Montero, 1997).

2.2 Generic model description

The overall goal is to cope with the nitrogen legislation at least cost, measured in total labour income. This income, summed over the entire sample, will be defined as:

$$AI_i^{Sc} = \sum_{i=1}^{n} (AI_i^{BAU} + Z_i^{Sc}) \qquad \text{Equation (1).}$$

with AI_i^{Sc} total labour income in a particular scenario (Euro);

AI_i^{BAU} the labour income realised in the business as usual scenario (Euro);

Z_i^{Sc} the total change of original labour income as a result of the imposed restrictions in the nutrient production (Euro).

Z_i^{Sc} will be mostly negative given the economic burden of (environmental) restrictions. Expanding the farm will obviously coincide with an increase of the income otherwise no expansion will be made. Given the maximising of the income per farm, the objective function can be defined as follows:

$$\text{Max}\, Z_i^{Sc} = A_i X_i^{afb} + B_i X_i^{mv} + C_i X_i^{ver} \qquad \text{Equation (2).}$$

with X_i^{afb} total nitrogen reduction by means of reducing the number of animals (kg N);

X_i^{mv} total nitrogen reduction by means of manure treatment (kg N);

X_i^{ver} total rise of manure production as a result of acquired tradable rights (kg N);

A_i lost income per unit nitrogen (euro per kg N);

B_i manure treatment cost per unit nitrogen (euro per kg N);

C_i extra income per unit N bearing in mind the manure treatment obligation per acquired right (euro per kg N).

When calculating the loss of income, the fixed costs will be kept at their pre-reduction level. This allows accounting for unused capacity when there is a reduction obligation. With expansion, a new fixed cost will be calculated and applied when expanding the production capacity of the farm through the acquisition of new manure rights. This new fixed cost is the same for each farmer. The different scenarios from the two models will be compared to the *business as usual* (BAU) where no norm or reduction obligation is enforced. The value for Z_i^{Sc} will be the *change* in labour income. This implies, with constant fixed costs, that the differences in gross margin will give the same result. Therefore in the model only gross margins were calculated. Of course, if a change in fixed costs occurred (expanding production), this change was accounted for.

Two lines of thinking will be explored: (1) a policy based on the usual CAC measures, and (2) a policy based on the more market oriented tradable permit system.

2.3 Description of the CAC model

With command-and-control techniques it is possible to reach the environmental objective through different ways and correspondingly different reduction costs. Besides the NH and NHc another key element (the norm) is introduced. The norm indicates the individual recycling capacity per animal. For simplification purposes, the individual recycling capacity is the same for each animal. The height of the norm thus depends on the ambition of the overall environmental plan.

To get an idea of the variation of the costs, six different scenarios were modelled:

Scenario 1: the introduction of the NH and the reduction obligation (meaning the reduction of the number of animals) for the real nitrogen production exceeding this NH.

Scenario 2: the introduction of the norm and the manure treatment obligation. Every pig farmer is obliged to reduce its nitrogen production exceeding the NH and to process the nitrogen production between the actual production and the production allowed by the norm.

Scenario 3: The N-production between the norm and the NHc must be eliminated by means of manure treatment or animal number reduction offering an alternative (reduction of the number of animals). This choice will be made after comparing the cost of the two alternatives. Still, the pig farmer is obliged to reduce its nitrogen production exceeding the NH. If the choice system interferes with the obligation system, the latter will prevail.

Scenario 4: the NHc is abandoned. The N-production exceeding the norm still has to be diminished through the reduction of number of animals.

Scenario 5: the NHc is abandoned. The N-production exceeding the norm is eliminated through mandatory manure treatment.

Scenario 6: the NHc is abandoned. The N-production above the norm must be eliminated by means of manure treatment or animal number reduction. The choice will be made after a cost comparison of the two alternatives already explained in scenario 3.

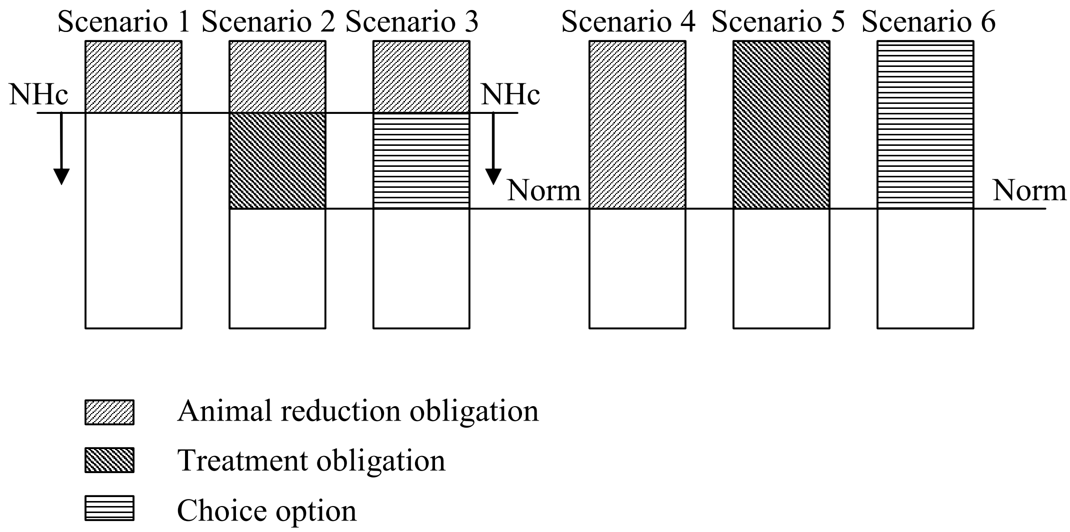

Figure 1. Visualisation of the six scenarios of the CAC model.

For each model the coefficient A, B and C as defined previously can be calculated. For the second model for instance those coefficients receive following values: A=$-\frac{BS_i}{we_i}$; B=$-P_{MV}$ and C=0. This is illustrated in the following table.

Table 1. The different scenarios under a command-and-control policy written as optimalisation problems.

	Reduction obligation above NHc	No reduction obligation above NHc
Reduction obligation	$\underline{\text{Max}}\, Z_i^1 = -\frac{BS_i}{we_i} * X_i^{afb1}$ $X_i^{afb1} \geq (we_i - NHc) * GAVV_i$	$\underline{\text{Max}}\, Z_i^4 = -\frac{BS_i}{we_i} * X_i^{afb}$ $X_i^{afb} \geq (we_i - Norm) * GAVV_i$
Manure treatment obligation	$\underline{\text{Max}}\, Z_i^2 = -\frac{BS_i}{we_i} * X_i^{afb1} - P_{MV} * X_i^{mv}$ $X_i^{afb1} \geq (we_i - NHc) * GAVV_i$ $X_i^{mv} \geq S_i$	$\underline{\text{Max}}\, Z_i^5 = -P_{MV} * X_i^{mv}$ $X_i^{mv} \geq (we_i - Norm) * GAVV_i$
Choice option	$\underline{\text{Max}}\, Z_i^3 = -\frac{BS_i}{we_i} * \left(X_i^{afb1} + X_i^{afb2}\right) - P_{MV} * X_i^{mv}$ $X_i^{afb1} \geq (we_i - NHc) * GAVV_i$ $X_i^{afb2} + X_i^{mv} \geq S_i$	$\underline{\text{Max}}\, Z_i^6 = -\frac{BS_i}{we_i} * X_i^{afb} - P_{MV} * X_i^{mv}$ $X_i^{afb} \geq (we_i - Norm) * GAVV_i$ $X_i^{mv} \geq (we_i - Norm) * GAVV_i$

With Z_i^{1-6} total change in labour income under the six different scenarios

BS_i gross margin (euro per GAVV);

we_i actual or real excretion coefficient (kg N per GAVV per year);

X_i^{afb} total reduction of nitrogen production as a result of a reduction of the number of animals (kg N);

X_i^{afb1} total reduction of nitrogen production as a result of a reduction of the number of animals concerning the nitrogen production above the NHc (kg N);

X_i^{afb2} total reduction of nitrogen production as a result of a reduction of the number of animals concerning the nitrogen production between the norm and the NHc (kg N);

X_i^{mv} total reduction of nitrogen production as a result of manure treatment concerning the nitrogen production above the norm (kg N);

P_{MV} manure treatment cost (euro per kg N);

$GAVV_i$ average number of finishing pigs present at the farm during a whole year;

NHc forfeit coefficient indicating the annual nitrogen production of a GAVV (kg N per GAVV per year);

S_i reduction obligation (reducing the number animals or manure treatment) regarding the part of the nitrogen production between the NHc and the norm (kg N).

The following lines are added to the second and third scenario:

$$\begin{aligned} &if\ (we_i - NHc) \geq 0\ then\ X_i^{afb1} = (we_i - NHc) * GAVV_i\ else\ X_i^{afb1} = 0 \\ &if\ (we_i - Norm) \geq 0\ and\ if\ \left((we_i - Norm) * GAVV_i - X_i^{afb1}\right) \geq 0 \\ &then\ S_i = \left((we_i - Norm) * GAVV_i - X_i^{afb1}\right)\quad else\ S_i = 0 \end{aligned} \qquad \text{Equation (3).}$$

The first line calculates the nitrogen production quantity (X_i^{afb1}) to be reduced when the real nitrogen production exceeds the NHc. The second line calculates how much nitrogen must be reduced and/or processed (S_i). For the first and second scenario there is no possibility to reduce the nitrogen production between the norm and the real excretion coefficient by means of a reduction of the number of animals, meaning that $X_i^{afb2} = 0$.

In *sensu stricto* there are only two cases were a decision problem has to be solved (scenario 3 and 6). The other four cases can be solved using simple Boolean mathematics. The analogy between the first three and last three is easy to detect. The reduction obligation of the nitrogen production exceeding the NHc has the consequence on the one hand that for the first three models the X_i^{afb} (total amount of reduced nitrogen through a reduction of the number of animals) will be split up into X_i^{afb1} (the reduction obligation above the NHc) en X_i^{afb2} (the possible reduction obligation between the norm and the NHc). In all scenarios, a reuse of the slack production quota by augmenting the number of animals kept is not allowed.

2.4 Description of the Tradable Substitution Rights model

In this paper substitution rights are defined as production rights allowing to produce an amount of nitrogen that can not be recycled or put in other words: for every kg of nitrogen per annum that a GAVV produces more than allowed by the norm, a farmer needs a substitution right. When these rights are given only to farmers exceeding the norm they will be able to sell these rights only if they reduce their nitrogen production. A reduction can be obtained by reducing the number of animals, triggering a better food conversion, setting up an animal selection program, etc. Here the reduction will only be achieved by reducing the number of animals or by paying for manure treatment. The total amount of rights (Ψ) will be defined as:

$$\Psi = \sum_{i=1}^{n} (we_i - Norm).GAVV_i^r \quad \text{for all} \quad we_i \geq Norm \qquad \text{Equation (4).}$$

This amount equals the total amount of nitrogen that needs to be reduced to obtain the environmental goal. Reducing the number of animals will result in a selling of substitution rights. Acquiring these rights will make it possible to keep more animals, although, this will imply manure treatment for the nitrogen produced with those rights. A ceiling is set on a maximum number of animals (MAX) and a maximum quantity of N-production (fixed by the expansion coefficient K). The more efficient a farmer produces nitrogen, the more he will be able to expand his production until MAX will be reached. Both conditions must be fulfilled at the same time. Finally, the farmer can also decide to keep his animals and to reduce its overproduction by means of manure treatment. All the possibilities for one individual farmer are summarized in the next figure.

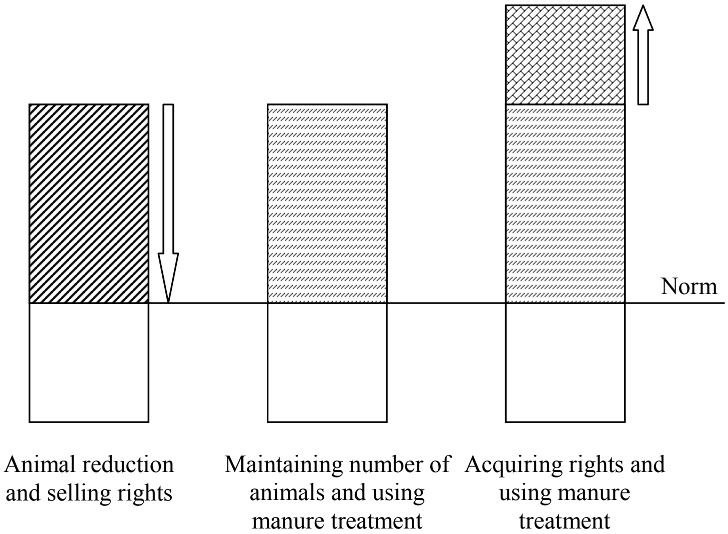

Figure 2. Visualisation of the three choice options in the tradable substitution rights model: animal reduction, manure treatment and production expansion.

The rights were grandfathered (least political resistance) on the basis of the current nitrogen excretion coefficient. The same norm and manure treatment price from the previous model will be adopted.

The model in its mathematical form can be written as follows:

$$\underline{\text{Max}}\ Z_i^{vr} = \left(P_{VR} - \frac{BS_i}{we_i}\right) * X_i^{afb} - P_{MV} * X_i^{mv} + \left(\frac{BS_i - FKN}{we_i} - P_{MV} - P_{VR}\right) * X_i^{ver}$$

$$\text{s.t. } X_i^{afb} + X_i^{mv} = we_i * GAVV_i - Norm * GAVV_i$$

$$MAX \geq \frac{X_i^{ver}}{we_i} + GAVV_i \qquad \text{Equation (5).}$$

$$K * Norm * GAVV_i \geq X_i^{ver} + GAVV_i * we_i$$

with Z_i^{vr} total change in labour income due to introduction of tradable rights (euro);

P_{VR} price of one tradable substitution right (euro per kg N);

FKN new fixed costs per new GAVV (euro per GAVV per year);

X_i^{ver} total rise of nitrogen production at a farm *i* as a result of acquiring extra tradable substitution rights (kg N);

MAX maximum number of GAVV allowed at a farm;

K expansion coefficient limiting the total nitrogen production per farm.

The price for the substitution rights will be obtained through iterations. The limited dataset will result in discontinue demand and supply curves for substitution rights and as a result no real equilibrium price will be obtained but rather an equilibrium interval.

2.5 Input data for the model

The different models were fed with accounting data from a test group of 190 pig finishing farms. This sector was chosen because it is seen as the sector contributing the most to the manure problem and seen as the sector with the least cost reducing possibilities. Nevertheless figure 3 shows a significant variation of real N-excretion coefficient and labour income. This is one of the key elements of a successful implementation of tradable permits.

Nowadays it is already technically and legally possible to proof the real nitrogen excretion coefficient. Moreover, Flanders has developed a large-scale measure and control grid that allows following up the nutrient flows from farmers. This indicates that the conditions for an operational establishment of the permit system are to a large extent fulfilled.

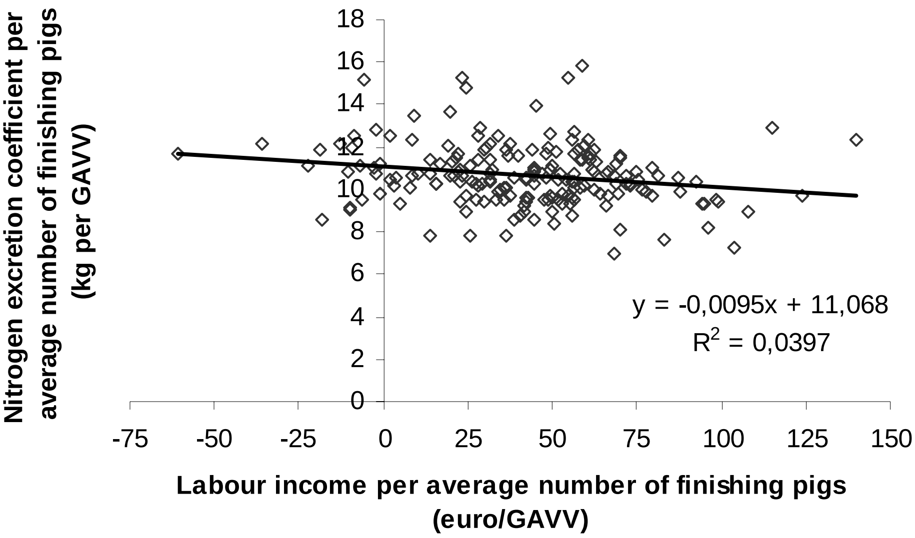

Figure 3. Labour income per average number of GAVV in relation with the nitrogen excretion coefficient per GAVV.

The economic data from 190 pig finishing farms are calibrated for annual fluctuations. Since the data date back from 1997, the economic data were actualised and the obtained reduction of nitrogen production from the last years has been taken into account. A reduction of 35 % of the total nitrogen production must be sufficient to comply with European legislation concerning the maximum allowed nitrogen recycling in Flanders (170 kg N per hectare per year). But as the pig finishing sector is perceived to be the main contributor to the manure problem, a more stringent norm of 40 % reduction will be adopted. Given the NHc of 13 kg N per GAVV per year (Decreet van de Vlaamse Gemeenschap, 1991), a 40 % reduction complies with a production of 7,8 kg N per GAVV per year. This production limit is referred to as the norm. The nitrogen production below this norm will be allowed at all times. The different scenarios will be compared to the *business as usual* (BAU) where no norm of reduction obligation is enforced.

Given the forfeit excretion coefficient of 6,5 kg P_2O_5 and 13 kg N per annum and a reduction cost of 6 euro per kg P_2O_5, the reduction cost for nitrogen could be estimated on 3 euro per kg. This rather blunt estimation will however not affect the mechanisms and the idea of this study. The predicted N production for the 190 farms at large is 1.211.965 kg N.

3 Evaluation of the results

3.1 Results of the CAC model

3.1.1 First scenario

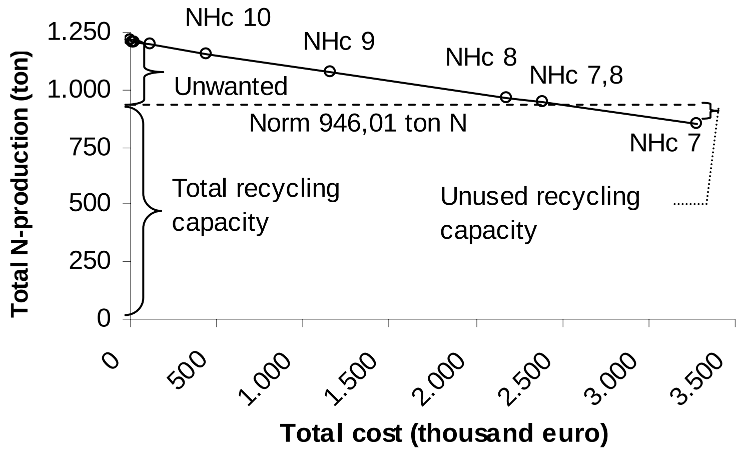

Figure 4. Cost-effectiveness for the first scenario.

In the first scenario, the production above the given NHc has to be reduced by a reduction of the number of GAVV. By lowering this coefficient the desired nitrogen output can be reached (NHc = 7,8) although at high costs (2.390.960 euro or more than 1/3 of the initial labour cost). This is entirely due to the reduction of labour income generating pigs (21,3 % or more than 25.000 animals). Since no norm was applied, the NHc must be reduced until 7,8 kg N per GAVV per year will the environmental goal be reached. At first sight the curve seems to be linear. However, for the highest values of the NHc a minor bending of the curve can be observed. Lowering the NHc from 11 to 10 coincides with a strong cost increase. This is an indication that most pig farmers already have a real excretion coefficient lower than 11 which implies that the NHc set by the government (13 kg N per GAVV per year) is an overestimation.

3.1.2 Second scenario

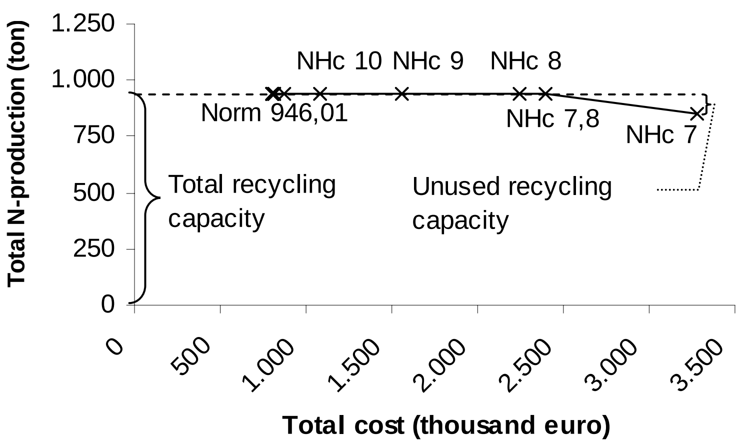

Figure 5. Cost-effectiveness for the second scenario.

In the second scenario the norm is introduced (7,8 kg N per GAVV per year). This means that at each nitrogen production level the environmental goal will be reached. Producing between the norm and the NHc implies a manure treatment obligation. The higher the NHc was set, the lower the costs to reach this goal meaning a higher cost to reduce the number of animals than to process the excess nitrogen production. The lowest cost was obtained with a NHc of 16 (806.460 euro). When the NHc reaches 7,8 the curve bends and follows the same path as under the first scenario. This is logic because the manure treatment obligation loses all meaning under this level.

3.1.3 Third scenario

With the third scenario a choice between manure treatment and animal reduction obligation is introduced for the nitrogen production above the NHc. As a result the cost to comply with the environmental goal is further reduced. The lowest cost is reached with the highest NHc. The curve of this third scenario is very similar to that of the second scenario and therefore not shown here.

3.1.4 Fourth, fifth and sixth scenarios

In the following three scenarios, the first three scenarios were repeated but the NHc was abandoned. With the abundant nitrogen, production will be dealt as follows: fourth scenario: reduction of the number of animals, fifth scenario: manure treatment and sixth scenario: a choice between the first two options. The outcome of these three scenarios will be the same as the former three scenario with NHc 7,8 for the first one and NHc 16 for the following two. Results are summarised in table 2.

Table 2. Comparing scenario 4, 5 and 6 (labour income and total costs in 1.000 euro; recycled, treated and produced quantities in ton nitrogen).

	AI	Total Cost	GAVV	Recycled N	Processed N	Total production N
Sc. 4	4.717,01	2.390,96	95.775,10	943,14	0,00	943,14
Sc. 5	6.301,51	806,46	121.283,60	943,14	268,82	1.211,97
Sc. 6	6.324,96	783,02	120.073,56	943,14	254,37	1.197,52

3.1.5 Discussing the CAC scenarios

The first scenario reaches the environmental goal only at NHc 7,8. All other scenarios comply with this goal at any time but obviously at different costs. The cost reducing effect of introducing choice in the third scenario can be observed when lowering the NHc but disappears entirely reaching the norm. Once reached, the three scenarios follow the same path.

The non-linearity of the curve of the first scenario would be more explicit when a higher correlation between AI and N excretion coefficient would exist (the higher the coefficient, the lower the AI per animal). The curves for the first three scenarios start at NHc 16 because of no relevant information retrievable with higher values for NHc meaning that every pig finishing farm realises a N excretion coefficient lower than 16. Lowering the NHc results in higher costs. Moreover, with a decrease of the NHc value a growing marginal reduction cost is observed. This indicates that with decreasing NHc more and more farmers fall under the regime of the animal reduction obligation.

Abandoning the NHc has the obvious effect that the simulation no longer results in a curve but in a single point. For the fourth scenario this point coincides with the point with NHc 7,8 from the first scenario, for the fifth scenario with point NHc 16 of the second scenario and for the sixth scenario with point NHc 16 of the third scenario.

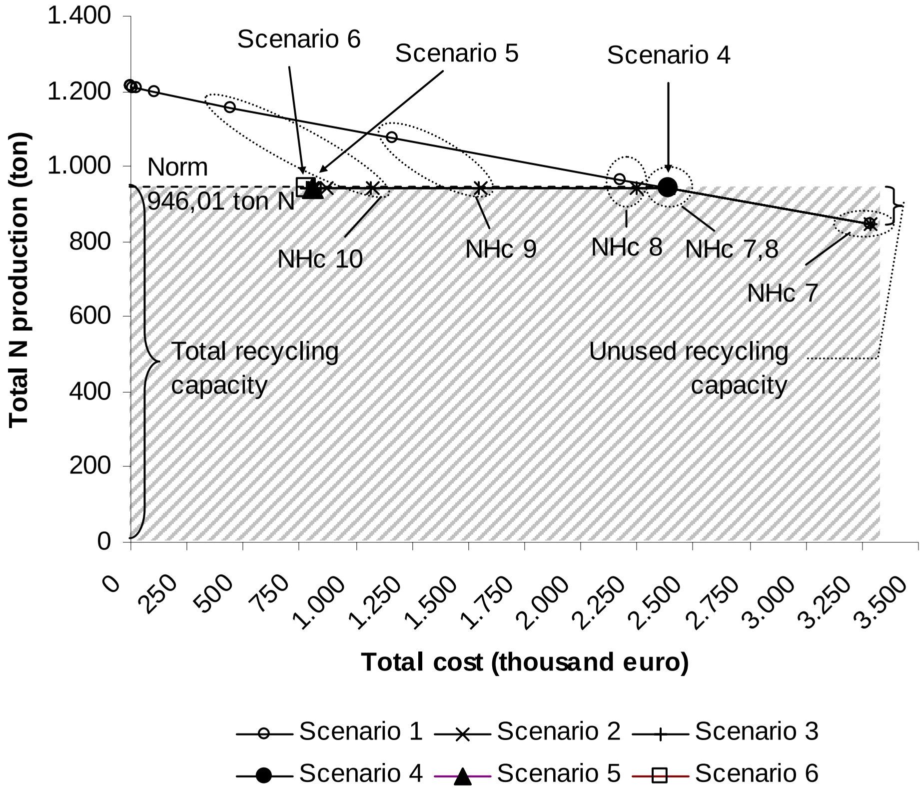

Figure 6. Visualising the results of the first model.

3.2 Results of the Tradable Substitution Rights model

3.2.1 Supply and demand curve

By means of iteration a demand and a supply curve for substitution rights could be derived. The best fit of the demand curve was through a logarithmic function ($R^2 = 0,97$). The supply curve showed an explicit sigmoid course and could be fit almost perfectly by means of a third degree equation ($R^2 = 0,99$). When looking at the supply curve, it becomes clear that some pig finishing farms are willing to offer their substitution rights for free. This indicates that for these farmers the gross margin will not cover the extra costs for the obligatory manure treatment when keeping the offered substitution rights. The supply curve has a vertical asymptote at x = 268.821. This corresponds to the total N production that can not be recycled. The *theoretical* equilibrium price of 6 euros could be derived graphically. *Theoretical* because with the model no perfect demand equals supply could be established due to the discontinue character of the two curves. Therefore the *practical* equilibrium price is an interval. This *practical* interval will be discussed next.

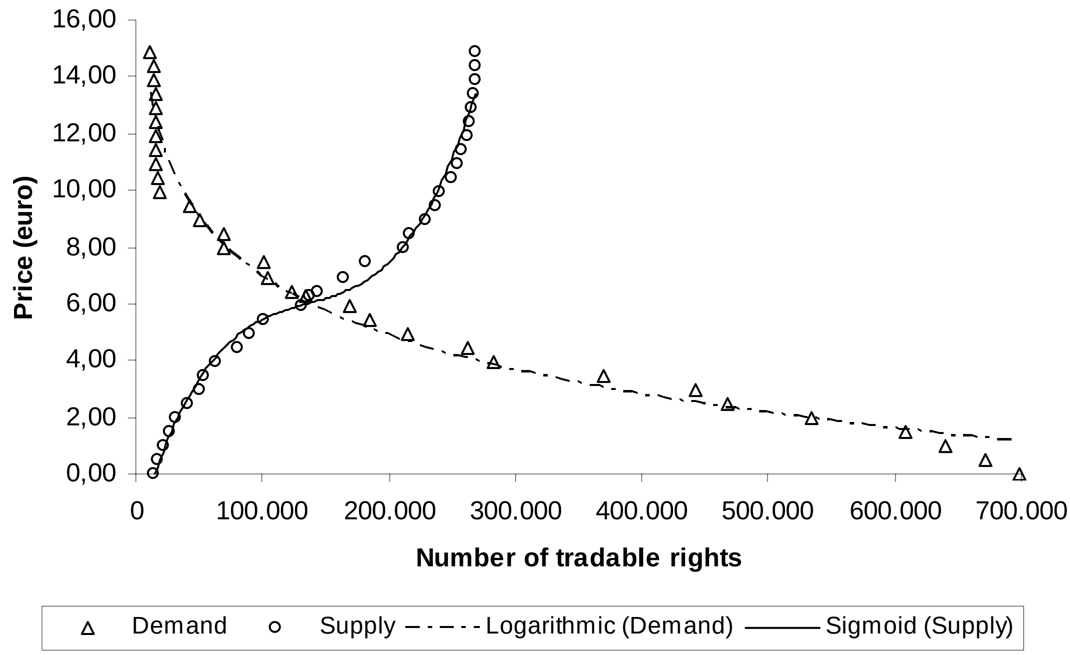

Figure 7. Demand and supply curve of substitution rights.

$$P_{SR} = -2{,}9326.Ln(Q_V) + 40{,}424$$ Equation (6).

$$P_{SR} = 3.\exp(-15.(Q_A)^3) - \exp(-0{,}9(Q_A)^2) + 0{,}0002.Q_A - 2{,}0764$$

For a price of 6,18 euro more rights (5.473) will be asked than offered. Assuming that everyone gets the amount of rights asked for at a certain price this mismatch will results in a creation of extra rights and consequently an excess of the total N surplus. In reality, no such excess will be registered because no creation of rights will be allowed. When augmenting the price with one eurocent more rights will be offered (2.772) than asked for. This implies that a part of the allowed nitrogen production will not be used. For the further analysis, the price of a right was fixed on 6,19 euro because this produced the tiniest gap between demand and supply. It is worth noting that there are always farmers not willing to participate at a given price. Therefore the total sum of suppliers of and buyers for rights do not necessarily equal the total number of farms in the test group. In perfect equilibrium, the price paid or received for the rights will be budget neutral for the sector as a whole. This as a result that no rights are transferred across sector borders. It will of course influence the individual labour income.

3.2.2 Market players

When looking at the market players the supply group of rights have a lower labour income than the demand group for rights although this does not count for everyone in the group. Remarkable is that 20 farms do not succeed in even realising a positive labour income. It is normal that these farms will sell all their rights.

Figure 8 illustrates that the fear for a take-over of the smallest farms by the biggest farms is not justified. Although mostly small farms are willing to sell their rights at the fixed price, the buyers are situated in almost every category. The reason however is not that big farms are unable to expand their production due to the double production limit because no farm reached these limits from the beginning. Remarkably even some big farms will sell their rights.

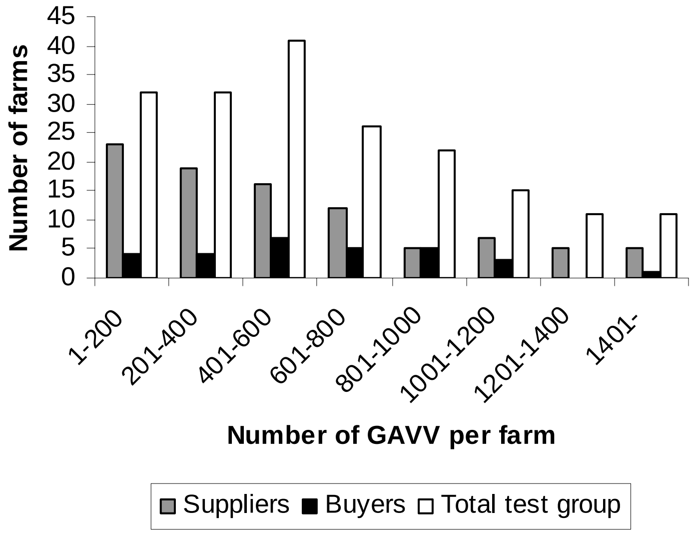

Figure 8. Distribution of all suppliers, all buyers and the entire test group according to the number of GAVV per farm.

3.2.3 Efficiency improvements

When looking at the N excretion coefficient of all farms, one can observe that in general more efficient farms (in terms of nitrogen production per animal) will buy rights from less efficient farms. This difference between the two groups can be clearly observed despite the weak correlation between labour income and N excretion coefficient. The difference between the average coefficient (in kg nitrogen per GAVV per year) of the group of suppliers (10,77) and of the group buyers (9,32) clearly illustrate this difference. Even when taking the weighted average. This difference is confirmed (respectively 10,37 and 9,01). This illustrates clearly that the trade of these rights will result in a shift of production capacity from less efficient farmers to more efficient farmers according to the theory of Figge and Hahn (2004). As an extra consequence the weighted average for all the farmers will drop and make the sector as a whole more efficient.

3.2.4 Sensitivity analysis

As a benchmark for the sensitivity analysis, the reference value for the price of the substitution rights is 6,19. The results are summarised in table 3. Changing the cost for manure treatment (P_{MV}) will change the equilibrium price but will not change the amount of rights traded. This is the result of an equal shift of the demand as well as the supply curve. A rise of the manure treatment cost will result in a lower AI and as a consequence an increased total cost.

Table 3. Sensitivity analysis on the trade of substitution rights.

		P_{SR} (€)	Demand of rights	Supply of rights	Treatment (kg N)	Production (kg N)	$GAVV_{Tot}^{Sc}$	AI (€)	Cost (€)
Equilibrium		6,19	135.200	137.972	266.049	1.209.193	123.852	7.015.801	92.175
P_{MV}	2,00	7,19	135.200	137.972	266.049	1.209.193	123.852	7.284.622	-176.646
	4,00	5,19	135.200	137.972	266.049	1.209.193	123.852	6.746.980	360.996
FK_N	24,79	7,02	166.262	165.529	269.555	1.212.699	124.503	7.226.102	-118.126
	49,58	5,43	100.322	101.053	268.090	1.211.234	123.668	6.846.353	261.623
K	1,4	3,74	54.981	56.312	267.491	1.210.635	122.630	6.658.025	449.950
	1,8	5,51	108.907	109.047	268.681	1.211.825	123.674	6.898.417	209.559
	2,6	6,42	143.859	143.737	268.943	1.212.087	124.283	7.093.653	14.323
$GAVV^{MAX}$	2000	6,09	136.081	135.881	269.021	1.212.165	123.873	6.967.081	140.895
	3000	6,25	140.748	137.972	271.597	1.214.741	124.589	7.040.213	67.763

Changing the value of the new fixed cost only has an effect on the demand curve for substitution rights. Lowering these costs result in an increased price and traded quantity. In turn lowering this cost makes the total number of GAVV to increase slightly (+ 652). This effect together with the lower fixed cost increases the labour income. Increasing the fixed costs result in an adverse effect.

Changing the expansion coefficient K will influence the expansion limit resulting in a change of the demand curve as illustrated in the next figure. A higher coefficient results in an increased equilibrium price and quantity. This in turn has a positive effect on the total number of GAVV and the individual and sectoral labour income. Increasing the coefficient with the same value (+0,4) leads to a smaller shift of the demand curve. This could mean that more and more farmers reach their expansion limit and will not be able to increase the size of their farm resulting in a diminishing shift of the demand curve. Figure 9 shows that it is likely that the demand curve is not shifted but rather turned over.

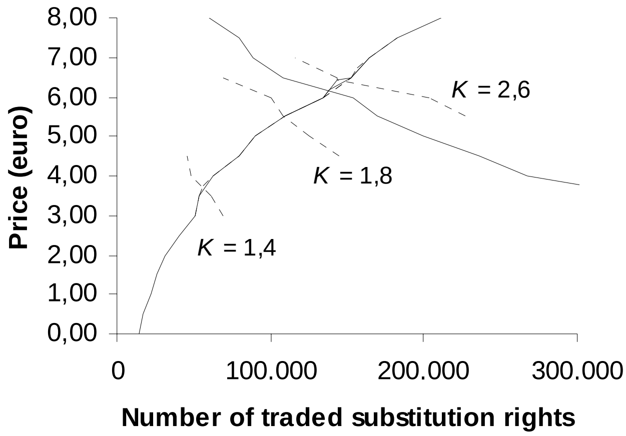

Figure 9: Sensitivity analysis of the expansion coefficient.

Changing the other expansion limit, maximum number of GAVV (MAX), will influence the total number of GAVV. With an increase of MAX the demand curve will shift to the right although not spectacular.

3.3 Cost effectiveness and efficiency analysis

The total labour income realised in 2003 when no restrictions or obligations were imposed (BAU scenario) was 7.107.976 euro. Introducing the environmental goal implied reducing the total quantity of nitrogen being recycled to 943.144 kg and this logically resulted in a cost. The lowest cost (783.017 euro) was obtained under scenario 6. With the introduction of tradable substitution rights, the same environmental goal was reached lowering the cost by a factor eight to 92.175 euro.

Table 4: Comparison of the results obtained under BAU, scenario 6 and under the system of tradable substitution rights.

	AI (€)	Cost (€)	Total N Production (kg N)	Treated N (kg N)	Recycled N (kg N)	$GAVV_{Tot}^{Sc}$
BAU	7.107.976	0	1.211.965	-	-	121.284
Scenario 6	6.324.958	783.017	1.197.516	254.372	943.144	120.074
Substitution rights	7.015.801	92.175	1.209.193	266.049	943.144	123.852

The total number of GAVV rises with 2,12 % following the introduction of tradable substitution rights. This is different from scenario 6 were a fall of the number of GAVV by 1,00 % was observed. The noted rise of the GAVV will definitely not put a burden upon sector related firms. The rise of the number of animals clearly indicates that farms with higher nitrogen excretion efficiency have bought rights from farms with lower excretion efficiency. This was already confirmed when looking at the efficiency improvements.

Table 5: Comparison of the simulation results of the two policy instruments.

	CAC model		Tradable rights model	
	Nitrogen	**Total cost**	Nitrogen	**Total cost**
TOTAL TO REDUCE	633.548	**783.017**	633.548	**92.175**
(a) Efficiency improvement	364.727	**0**	364.727	**0**
(b) Manure treatment	254.372	**763.116**	266.049	**798.147**
(c) Animal reduction	14.449	**19.902**	2.772	**- 705.972** (c + d)
(d) Reallocation	0	**0**	135.200	

In table 5, the reduction costs are split up by origin. The CAC model, sixth scenario, is put next to the tradable rights model. Starting from 121.284 GAVV excreting 13 kg N per GAVV per year according to the forfeit norm (1.576.692 kg N per year). When making the sum of the real excretion per farm, the total efficiency improvement (a) happened in the past can be calculated (364.727 kg N). This is of course equal for both models. While this happened in the past, no cost was accounted for. Manure treatment (b) counts for the highest cost for both the models, almost 800.000 euro. The reduction by means of animal reduction (c) accounted in the tradable rights model for 2.772 kg N but as explained above, this quantity reaches zero when there is a perfect match between the demand and the supply curve for the rights. Unlike the CAC model this cost can be recuperated by an increase in the animal production caused by a shift in substitution rights (d) resulting in a cost decrease of 705.972 euro. As a result, the total cost for the tradable rights model decreases until 11,77 % of the total cost of the CAC model, scenario 6, which is already the least cost scenario of all the CAC scenarios considered. The negative cost generated with the animal reduction shows how much is gained when shifting the production to more efficient farmers. Finally the total cost under the tradable rights model is only 1,30 % of the original labour income at the BAU scenario.

4. Conclusion

This study clearly shows that significant cost reductions (88 %) may be expected when introducing tradable substitution rights in the pig finishing sector. Since the model does not count for other individual efficiency improvements, a further elaboration of the model will result in extra cost reduction. When expanding the model to other sectors such as the poultry or cattle sector, even further cost reductions can be expected according to the theory (Noll, 1982; Montero, 1997). There was no evidence found that big farmers will take over all the small ones, although this was one of the reasons why tradable rights are still a non item in agriculture. Another reason is the high cost increase for new farmers when entering the market and the windfall profit for the current farmers when acquiring those rights for free (Hahn, 1989). This is still a point of attention but theoretically part of the answer can be found in the way the rights are distributed, as by using auctions mechanisms (e.g. Lyon, 1982; Barde, 2000; Tietenberg, 2001; Harrison, 2002) the windfall profits will be eliminated. Moreover, auctioning is accepted to be the most cost efficient and cost effective way to reduce pollution (Stavins, 1998).

The concept of tradable rights is also of importance to policy oriented activities related to the stock-breeding sector. European and Flemish legislation aim at the reduction of nitrogen pollution from agriculture. Substitution rights are already defined and when making these rights tradable, a significant cost reduction is predicted with this model. The success of this measure could be jeopardised by a lack of information concerning the real excretion. This, however, does not have to be true while already sufficient information and techniques are available to measure the real excretion e.g. well documented food conversion coefficients, tiny chemical sets available on the market to measure the real nutrient content in manure, etc. Given the broad control network set up by the government, a close monitoring of the real excretion can be done. Furthermore, even in a sector perceived as having homogenous MAC curves, sufficient differentiation of the reduction costs is available to result in substantial cost lowering effects when trading is allowed. Besides the pig finishing sector more sectors can join this trade resulting in further lowering of the transaction costs. All this shows that the introduction of tradable substitution rights does not need to be merely a theoretical exercise.

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