



Analysis

Markets of concentration permits: The case of manure policy

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ABSTRACT

Concentration permits are regarded as an interesting policy tool for regulating emissions where, besides absolute amounts, also local concentration is important. However, effects of governance structure, trading system and possible policy interventions in the permits' allocation are not yet well analysed and understood. This paper explores in how far tradable fertilisation standards can be seen as a concentration permit trading (CPT) system which can be fine-tuned for further policy intervention. Indeed fertilisation standards such as obliged by the EU Nitrate Directive can be regarded as local nitrate emissions limits, and thus concentration permits. A multi-agent spatial allocation model is used to simulate the impact of defining the manure problem in terms of concentration permits rather than conventional emission permits. Impacts are simulated in terms of environmental performance and increased reallocation costs. The model is applied on the Flemish manure problem.

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1. Introduction

Tradable permits or quotas have become an important tool for managing externalities and they are currently attracting an increasing interest in OECD countries (Kampas and White, 2003). Their main advantage is cost efficiency: a predefined environmental target can be achieved at minimum cost (Baumol and Oates, 1971). Assuming perfect market conditions (this is without transaction costs), the permits will be used by those who attribute the highest value to them (Tietenberg, 2003), regardless of their initial allocation (Montgomery, 1972). Tradable permits are useful when the emissions under consideration have no local impact on environment or population (Lejano and Hirose, 2005), as is the case for greenhouse gases and NO_x. In such cases it does not matter where the pollutants are emitted because it is only their overall concentration that has an impact on the environment. However, when emissions have an immediate, or an almost immediate effect, on the local environment, permit trading does not guarantee achievement of initial emissions targets for each local receptor. As a result of permit trading, emission hotspots can occur (Lejano and Hirose, 2005), locally affecting environment and population. Examples include toxins (lead, SO₂,...) and noise.

Therefore, Stavins (1995) argues that, in such cases, an ambient or concentration permit trading (CPT) system is theoretically preferable to a regular emission permit trading (EPT). A concentration permit is

defined as the granting of permission to deposit a quantity of pollutants at a specific receptor (Ermoliev et al., 2000). Theoretically, the market will enable a cost-efficient outcome (Montgomery, 1972). However, some authors believe that in practice, such systems generate high transaction costs and cannot achieve cost-effectiveness (Tietenberg, 1995). This complexity is seen as a major reason why, based on literature knowledge, no policies based on CPT have been developed so far.

However, simulations of well-described problems exist and may show the potential for CPTs, or facilitate the analysis of CPT effects. An example of such a well-described problem is that of manure and manure policy interventions, in regions with a high concentration of animal production. Basically, manure policies attempt to solve manure surplus problems at particular locations, by spreading the impact over wider areas, whilst safeguarding the carrying capacity of the environment at each location. The manure problem has been extensively described (e.g. Helming and Reinhard, 2009; Lacroix et al., 2005; Lauwers et al., 1998; Oenema et al., 2007; Wossink and Gardebroeck, 2006), making it a good case to increase our understanding of the opportunities for CPT.

The objective of this paper is to compare the CPT system with an EPT system, using the empirical case of the manure problem as a model for CPT. The Flemish policy case is used as an illustration. With a multi-actor spatial programming model (earlier described by Van der Straeten et al., 2010), the Flemish case is simulated with an EPT as well as a CPT regulation. This allows identifying specific market characteristics for tradable concentration rights, e.g. spread of environmental pressure, private costs for the emitters. The case research also makes possible

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impact analysis of supplementary policy interventions in the CPT market.

The paper is organised as follows. The paper starts by describing the possibilities and the theoretical advantages of both EPT and CPT. This section also explains the analogy of the manure problem with a CPT system. The use of Flemish manure policy, with its idiosyncrasies, is also specified. Section 3 describes the model used to analyse the EPT and CPT regulations. This makes explicit the spatial aspects of permit prices and illustrates how the costs and benefits from the trade in permits can be calculated. In the results section EPT and CPT systems are compared using five criteria: environmental effectiveness, economic efficiency, administrative costs, dynamic effects, wider economic effects and soft effects. Section 4 discusses the results and provides conclusions.

2. The Flemish Manure Policy as a CPT Case

2.1. Comparing CPT with EPT

Environmental policies to manage limited resources, or to prevent damage from pollution, can intervene at different levels of the pollution process. Regulation of input use is very common in environmental policy design. This approach is appropriate when the damage from pollution relates solely to the level of input use. Even more precise are policies regulating emissions, instead of inputs or outputs. However, in many cases, the damage from pollution depends more on the spatial concentration of pollutants than on total emissions. The location of emissions therefore matters, especially where they lead directly to spatial differences in environmental state and impact. Looking in more detail at the damage from pollution, exposure and the risk profile of those exposed to it, can also play a role in determining the pollution impact (Stavins, 1995).

Concentration permits are policy measures that account for these spatial differences. They are defined as limits on the emission per unit of output, per unit of effluent or per receptor (Bruneau, 2005; Ermoliev et al., 2000). They can enter a trading system, but the use of the right remains linked to the effluent or receptor side. Ambient or concentration permit trading systems are terms which are used interchangeably in the literature. In the remainder of the paper, we will use the term concentration permit trading (CPT).

Stavins (1995) argues that, theoretically, optimal environmental policy should intervene at the highest detail level of the pollution impact cycle. Pollution management should therefore take into account concentrations, exposure and the risk profile of those exposed as the main indicators of environmental damage. The advantage of controlling risk and exposure, rather than input use or total emissions is twofold. First, the threshold of exposure cannot be guaranteed when only total emissions are controlled. Second, more opportunities emerge for adapting the production process when exposure rather than total emissions is minimised. Exposure minimisation can be achieved by changes at the production location (including input or output-based measures), as well as by minimising emissions or a combination of both, whilst emission minimisation is only restricted to minimising the emissions themselves. In other words, with CPT one can reduce damages even if total emission is not reduced, simply by relocating the activities. Main disadvantage is the higher cost to spread the total emission in order to respect the local thresholds.

Despite the theoretical advantages of CPT systems compared to EPT, until now the use of CPT systems has not been widely described in the literature. However, the system can offer significant advantages compared to EPT, particularly for air pollution, as it can prevent the concentration of pollutants (Atkinson and Tietenberg, 1987). The main reason for not using CPT, however, is the likely increase in public and private transaction costs associated with policy intervention at a greater level of detail in the pollution process (Stavins, 1995; Vatn,

1998). Vatn (1998) argues that it is generally more costly to undertake regulation on dispersed emissions, rather than on well-demarcated inputs into the economy. Therefore, Vatn (1998) states that an input-oriented environmental regime is potentially more efficient than an emission-oriented one, if transaction costs are taken into account.

Where the spatial dimension of resource use or emissions does matter, the EPT system is sometimes combined with spatial limitations to permit trading (Atkinson and Tietenberg, 1987; Tietenberg, 2003). The RECLAIM programme in the U.S., for example, makes a distinction between two areas (coastal and inland). Because the predominant wind direction from the coast is inland, EPTs can only be transferred within the same area or from the coast to the inland area. EPT transfers from the inland area to the coast are prohibited (Harrison, 2003). Similar trade rules have been introduced in the Dutch Nutrient Quota System. Phosphate production is regulated using animal-based production rights. Each farm was allowed to produce 125 kg P₂O₅ per hectare of land. Farmers producing more manure, in terms of phosphate, need additional manure production rights. These rights are tradable between farmers. Also here, distinction is made between two regions: a manure surplus (average phosphate production higher than 125 kg per hectare) and a manure deficit (with phosphate production below 125 kg/ha) region. Trading of rights is permitted within each region and from the surplus region to the deficit region (Wossink, 2003).

Choosing between policy instruments needs objective evaluation criteria. In our CPT–EPT comparison, we will use the set of objective criteria, as suggested by Tietenberg and Johnstone (2004): environmental effectiveness, economic efficiency, administrative costs, dynamic effects, wider economic effects and soft effects. Environmental effectiveness measures the extent to which the policy meets the environmental objective, whilst the economic efficiency indicates whether or not this is achieved at the minimum cost. Administration costs allow the checking of whether transaction costs (cost to set-up, implement and control a policy) remain at an acceptable level. The dynamic effect of an environmental policy instrument is the extent to which the policy generates incentives for technological innovation. Changes in competitiveness and distributional effects are the wider economic criteria and, finally, the soft effects refer to the attitude and the behavioural response driven by the environmental policy instruments.

For such a broad evaluation, operational tools for policy analysis are necessary. In the current paper, the model of Van der Straeten et al. (2010) is used to quantitatively simulate emissions, allocation of these emissions and resulting costs, thus directly providing insight into some of the OECD evaluation criteria (measures of environmental effectiveness and economic efficiency). But also indirectly a discussion is possible on administrative costs, dynamic effects, wider economic effects and soft effects.

To show the potential of the modelling framework, it has been applied to the case of Flemish manure policy, for which data are available to enable a quantitative analysis of a currently applied CPT.

2.2. Description of the Flemish Manure Problem and Policy as a CPT Case

The manure problem relates to the over-production of animal manure, and thus the risk of excessive nitrogen and phosphate emissions at given loci. The problem has been identified in many countries or regions, including the Netherlands and Flanders. The Dutch Nutrient Quota System is given above as an example of a policy to control the externalities of intensive livestock production. Flanders, a region within Belgium and adjacent to the Netherlands, faces a similar problem with animal concentration and potentially localised manure emissions. The Flemish manure policy is, together with the Dutch manure policy, probably the most detailed policy in the world

for controlling the use and production of nutrients originating from agricultural sources.

The Flemish manure policy limits the amount of nutrients (N and P₂O₅) from animal manure emissions using fertilisation standards. Van der Straeten et al. (2010) describe these standards of organic nitrogen use as Nutrient Allocation Rights (NARs). One NAR gives the farmer the right to emit 1 kg of organic nitrogen. NARs are allocated to individual farms based on their land use. As an example, each farm receives 170 NARs for organic nitrogen per hectare of arable land. The emitted nutrients must be used on that specific hectare of land, which makes NARs an example of concentration permits. NARs have also been categorised as tradable emission rights (Lauwers et al., 2003), because the policy allows transactions of NARs between farmers. Contrary to other examples of emission permits, the right to emit is locally fixed and the emission can be traded (Buysse et al., 2008). Therefore, the NARs are similar to, and can be described as, an example of a CPT system.

Flemish manure policy prescribes how individual farms have to deal with their emissions (manure). The emission produced per farm is calculated based on the number of animals per animal type, feeding technique and housing type. All manure produced must either be emitted within the available concentration rights (NARs) or the farm has to opt for emission abatement, which involves manure processing. The initial allocation of concentration rights is based on land use, but the right to emit an amount of manure can be traded between farms. As such, the farms have three allocation choices. First, they can use their produced emissions (manure) within their own concentration permits. Second, the farms can transport their emissions to other farms with unused concentration permits, which mean permit trading. Third, the farm has the option to engage in emission processing. Manure processing or treatment is used as a comprehensive term for all technologies which remove or recover nutrients from manure (Flotats et al., 2008). As a result, Flemish manure policy has created a market for manure (Van der Straeten et al., 2010), which can now be seen as an example of the demand and supply of concentration permits. Manure processing is seen as an end-of-pipe abatement solution for pollution. In this paper, we do not consider a possible fourth option – i.e. a reduction in animal production or other changes in the activities of the farm – as this would require a more complex simulation and optimisation model and goes beyond our research objective to explore the manure problem as a case of concentration permit trading.

3. Method

3.1. The NAR Market Model

Geographically, the concentration permits (NARs) are evenly spread, but the production leading to emissions is regionally concentrated. This spatial difference between demand and supply of NARs can be simulated using a spatial price equilibrium (SPE) model. The SPE model computes the supply prices, demand prices and emission trade flows, satisfying the equilibrium condition. The equilibrium condition states that, when trade between two regions occurs, the demand price of a NAR equals the supply price plus the transportation cost. Trade does not occur when the demand price is lower than the supply price plus transportation costs. Transportation of the emissions or reallocation of the emission sources, and their costs, are the main characteristics that differentiate concentration permits from traditional emission permits. Both transportation and its costs are captured in the SPE model. The individual demand and supply behaviour is simulated for each agent by a mathematical programming model that assumes cost minimising behaviour when emissions are allocated.

The combination of the individual mathematical programming models for each agent and the overall SPE model gives a Mathematical Programming Multi-Agent Simulation model (MP-MAS), as devel-

oped and described in more detail in Van der Straeten et al. (2010). The model uses data from each individual farm, with regard to its location, production and NARs, and calculates a farm-specific supply or demand of NARs. As the MP-MAS allocation model is able to differentiate costs relating to each allocation option at farm level and is able to endogenously simulate market prices for the NARs, it will be applied in this paper for the CPT–EPT comparison.

In order to make the analogy between the manure problem and the CPT system explicit, we start from the equation in Stavins (1995) in which the quantity of traded permits (t_n) by actor n is defined as:

$$t_n = |u_n - r_n - q_{0n}| \quad (1)$$

with u_n the unconstrained emission, r_n the emission reduction or abatement and q_{0n} the initial allocated permits. Translated to the manure case, this equation becomes:

$$TP_n = |NP_n - NT_n - NAR_{0n}| \quad (2)$$

in which TP_n stands for the traded permits per year by farmer n , NP_n the nitrogen production per farmer per year, NT_n the volume of treated (processed) nitrogen per year and NAR_{0n} the initial NAR allocation per farmer per year.

Eq. (2) is the driving factor to permit exchange and formalised within the NAR market model as described by Van der Straeten et al. (2010).

The following equations represent the model in algebraic notation where variables are indicated by Greek symbols whilst parameters are indicated with Latin symbols.

$$\text{Minimise } \sum_a [\sum_a \text{abatecost}_a * \mu_{na} + \sum_a \text{disposalcost}_a * \sigma_{na} + \sum_{ma} \tau_{nma} \text{distance}_{nm} * \text{transportcost}_a] \quad (3)$$

s.t.

$$NAR_n \geq \sum_a \text{excretion}_a * \text{animals}_{na} - \mu_{na} - \sum_{ma} \tau_{nma} + \sum_{ma} \tau_{mna} \quad [\rho_n] \quad (4)$$

with $n, m \in N$, where N denotes the farm population and $a = (1, \dots, A)$ indexes the livestock category.

The model uses abatecost_a , disposalcost_a , distance_{nm} , transportcost_a , NAR_n , excretion_a , animals_{na} as given parameters.

abatecost_a is the abatement cost for manure per unit of nitrogen for a given livestock category (euro/kg N).

disposalcost_a is the disposal cost or spreading cost for manure per unit of nitrogen for livestock category a (euro/kg N).

distance_{nm} is the distance between two firms n and m (km).

transportcost_a is the unit transport costs for manure of a livestock category a (euro/km/kg N).

NAR_n is the available nutrient allocation rights at firm n in a specific year (kg N).

excretion_a is the excretion coefficient to calculate the amount of manure based on the present animals (kg N/present animal).

animals_{na} is the number of present animals per year.

μ_{na} , σ_{na} , τ_{nma} are positive variables and ρ_n is the dual variable of constraint (4).

μ_{na} is the amount of emission abatement per year (kg N).

σ_{na} is the amount of disposed manure per year (kg N).

τ_{nma} is the amount of traded NARs per year, between farm n (buyer) and m (seller) (kg N).

ρ_{na} the dual variable of constraint (4) and indicates the price of NARs of farm n per year (euro/kg N).

The model minimises all direct costs related to satisfying the concentration permit constraint per year: the sum of emission abatement ($\sum_a \text{abatecost}_a * \mu_{na}$), manure disposition ($\sum_a \text{disposalcost}_a * \sigma_{na}$), and emission reallocation ($\sum_{ma} \tau_{nma} \text{distance}_{nm} * \text{transportcost}_a$). The model focus is on the decision related to managing emissions not on changing

production and therefore, the production decision such as the number of present animals is not variable in the model.

Optimising the model simultaneously for all farms makes it possible to simulate the price of NARs endogenously. The price of NAR is firm-specific and is represented in the model by the dual variable of the firm level NAR constraint (4). The firm specific price reflects the spatial diversity in supply and demand of NARs. The exchange of NARs causes a transfer of income from net buyers of NARs to net sellers of NARs. The net costs per farm can be calculated by using the objective function (3) plus the costs or income from the exchange of NARs ($\sum_{ma} \tau_{nma} * \rho_m - \sum_{ma} \tau_{mna} * \rho_n$) as follows:

$$\begin{aligned} & \sum_n \text{abatecost}_a * \mu_{na} + \text{disposalcost}_a * \sigma_{na} \\ & + \sum_{ma} \tau_{nma} * \text{distance}_{nm} * \text{transportcost}_a \\ & + \sum_{ma} \tau_{nma} * \rho_m - \sum_{ma} \tau_{mna} * \rho_n \end{aligned} \quad (5)$$

The transportation ($\sum_n \sum_{ma} \tau_{nma} * \text{distance}_{nm} * \text{transportcost}_a$), manure disposal costs ($\sum_a \text{spreadcost}_a * \sigma_{na}$) and abatement costs ($\sum_n \sum_a \text{abatecost}_a * \mu_{na}$) are additional costs at sector level, whilst the concentration permit costs ($\sum_n \sum_{ma} \tau_{nma} * \rho_m$) and benefits ($\sum_n \sum_{ma} \tau_{mna} * \rho_n$) are the result of redistribution within the agricultural sector.

The net cost can be negative for the net sellers of concentration permits, which means that farms with more NARs than needed for manure supply have a net income from the manure policies. The calculation of the price for NARs and the resulting redistribution across locations and between farmers is explained in the next subsection.

3.2. Price of NARs

Under perfect market conditions and EPT assumptions, a uniform market price can be identified (Baumol and Oates, 1971). In CPT, however, the unequal distribution of emissions and NARs, and the distance between suppliers and demanders become important in terms of price setting. Stavins (1994, 1995) assigns transportation costs the same characteristics as other transaction costs, because of their similar influence on market equilibrium. In the case of the NAR market, the buyer of the permits bears the transportation costs. This results in a downward shift in the demand curve (Fig. 1). Similar to transaction costs (Stavins, 1995), transportation costs lead to a difference in the price received by a seller of the rights (P_S) and the price paid by the demander (P_D). The traded volume decreases from Q_m to Q_T . However, the shift in the demand curve (Fig. 1) is not the same for the whole range of exchanged NARs, because the transportation costs for emissions vary.

Each animal type – as a combination of species, age and feeding system – produces manure with its own characteristics (e.g. nutrient

content and dry matter content). The model in the current paper considers four different manure types, each with specific nitrogen content, resulting in a different transportation cost per kg of nitrogen. This results in a discontinuous shift in the demand curve for NARs. A farm will transport manure by manure category in order of the associated transportation cost. The cheapest type of manure results in a small downward shift in the curve, the type with the highest transportation cost will result in a larger downward shift.

The shift in the demand curve also depends on the spatial dimension of the NAR market. NARs located far from the emission source bear higher transportation costs. The resulting demand curve shifts more to the left, so the observed price of the NARs is lower, at a lower traded volume. In regions with high emission concentrations, competition for concentration rights is high. Farms in regions with highly concentrated sources of emission have to choose between buying expensive local NARs or reallocating their emissions to a region with lower prices, whilst bearing higher transportation costs. This specific characteristic of the NARs results in spatial differences in market prices, which has also been demonstrated for manure emission rights (Van der Straeten et al., 2010; Van der Straeten and Buysse, 2009).

3.3. Specification of Costs and Benefits from Trade of NARs

The price of the NARs (P_{NAR}) generates a reallocation of revenues within a sector, if the actual use is different from the initial allocation, i.e. when $\sum_n |TP_n| \neq 0$. In the case of manure emission rights in Flanders, the distribution of the rights is based on land use, whilst the emission is based on animal production. Correlation between land use and animal production is strong for cattle farms, but much smaller for specialised animal farms, which have a significant NAR shortage, and specialised arable farms, which have a significant NAR surplus.

The distributional effect between agents is one of the OECD objective test criteria (see Section 2.1: wider effects). Evaluation of this criterion requires an in-depth analysis of costs and benefits from the NAR trade. Although the emission source, manure, is rather heterogeneous and results in a discontinuous demand curve for NARs, the concentration emission from manure can be expressed homogeneously as kg N/ha. The costs for the NAR buyer are then the costs for the bought permit ($P_S Q_T$) plus the transportation costs as shown in Fig. 2. The costs of transporting the emission is, however, not equal to $(P_D - P_S) Q_T$ because our calculation uses the marginal transportation cost as a proxy for the average transportation cost per right. Fig. 2 shows that the marginal transportation cost is generally higher than the average transportation cost if transportation costs are not homogeneous for all the emissions. If more than one type of manure is transported, the marginal costs reflect the costs of the

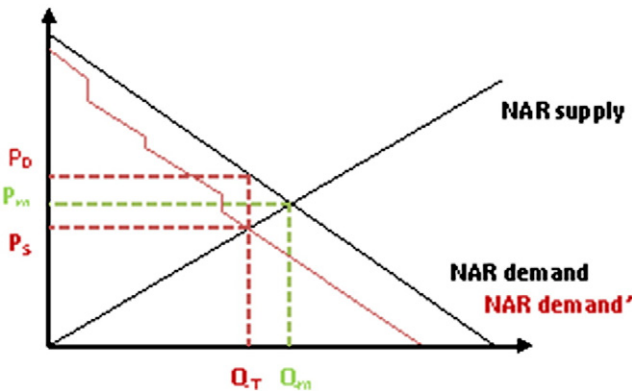


Fig. 1. Graphical representation of the market of concentration rights and the effect of transport costs on the market equilibrium.

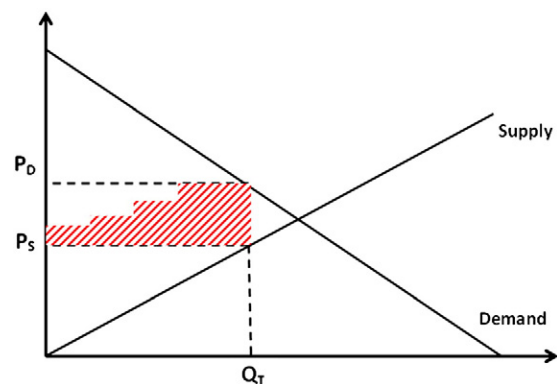


Fig. 2. Transportation costs in the manure market.

most expensive type of transported manure. The average transport cost will be lower because also less expensive manure types are transported.

Graphically, only the shaded part in Fig. 2 is the actual transportation cost and not the full area a , b , P_s , P_d .

3.4. Data

For our simulations, we used data for 2008, obtained from the Flemish Land Agency (FLA or Vlaamse Landmaatschappij, VLM), which is a public body controlling manure exchange between farmers. The dataset contains the complete farm population and offers data about crops, manure production, NARs and the manure allocation behaviour for each Flemish farm. In total 36,073 farms are included in the model. These farms have a total area of 644,000 ha. With 23,444 farms holding animals, this results in a total nitrogen production of 121 million kg and a phosphate production of 58 million kg. More than half of the nitrogen is produced by cattle and more than one third by pigs. Poultry is the third most important nitrogen producer (8% of total nitrogen production). A quarter of the Flemish farms are manure surplus farms, i.e. they produce more manure than they can spread on their own land (with respect to NARs).

4. Results

The NAR system, issued from the Flemish manure policy, and to be seen as a case for CPT system, is compared with a hypothetical and simpler, tradable emission permit (EPT) system. Under the CPT system, the farm's emissions are spatially limited by the imposed maximum concentration rights. The simpler system of tradable permits (EPT) gives the farms more degrees of freedom, because they can produce the same quantity of emissions without fully tackling the problem of emission concentrations. In fact, in an EPT system, farms would face limits at considerably higher concentration levels. In the case of manure, the amount of manure per ha, under an EPT system, will only be determined by the agronomical maximum, beyond which production, or utility, would be reduced. For the sake of our simulations, this agronomical maximum is set at 500 kg N/ha on grassland, 400 kg N/ha for most other crops and 200 kg N/ha for crops that tolerate only a limited amount of nitrogen, such as onions, peas and beans. These maxima are realistic and comparable to amounts applied in the past, before the manure regulation was imposed.

Under the EPT policy, farmers have to obtain enough rights to dispose all the manure produced on their farms. However, the main difference with CPT is that the right is not attached to a specific parcel. A farmer can obtain the right for emitting the manure, up to the agronomical maximum, on his own parcels. This makes this type of policy less costly than a policy with more severe local concentration limits. To be able to focus on the effect of introducing the CPT, the total available NARs is assumed equal under EPT as under CPT. At micro level it is the agronomical maxima which define the manure use, whilst at macro level this manure use is defined by the imposed equality of available NARs between both scenarios.

4.1. Economic Efficiency

For the analysis of economic efficiency, only the sum of the private costs borne by farmers is taken into account. As pointed out earlier, any actual concentrations above the concentration limit must have a social cost, beyond the private cost. However, we have no quantified damage function from manure concentrations. Hence, the 'net costs' are the private costs of regulation, and not the full 'social cost' of the regulation. The environmental impact is discussed in the next subsection.

The net private costs for all manure emissions in Flanders, under the EPT system, are estimated to be 84.89 million Euros (on an annual basis). More than half of these costs are disposal costs (56%), 43% are processing costs and the remaining 1% are transport costs. The more restrictive CPT system increases the net costs to 92.64 million Euros for all manure emissions. The difference of 7.75 million Euros can be seen as a consequence of the higher transportation costs of the emissions under a system based on concentration permits (NARs). The benefits of manure use, in terms of improved crop yield or increased substitution for organic fertilisers, are not taken into account here, but yields are expected to be higher for the CPT system, because the manure is better distributed over more plots.

The results confirm the statement of Stavins (1995) that emission control based on concentration permits might increase total costs. The costs in our case are still a lower estimation because we have not taken transaction costs, i.e. costs for information, negotiation or control into account. Also the public control costs are not considered. The actual manure emission is monitored through soil samples and sporadic by helicopter controls. Transportation activities over longer distances are controlled by GPS. The cost of GPS markers is imposed on the private farms and is included in the 7.75 million Euro estimation. The cost of helicopter control is met from public funds and is not included. The above mentioned fertilisation value of manure is specific to our case, and cannot be extrapolated for a CPT–EPT comparison.

Drawing a distinction between sellers of NARs (i.e. farms producing less nitrogen than their available NARs) and buyers of NARs (i.e. farms producing more nitrogen than the available NARs) we can see that the increase in the net private costs from a CPT system compared with an EPT system is mainly increased costs of buying permits (from 67 to 94 million Euros or +40.3%). Sellers experience a decrease in net private costs using a CPT instead of an EPT system from 17 to –1 million Euros due to the increased market value of the sold NARs. The sellers of NARs gain additional benefits from the improved fertilisation of their crops, although this is not taken into account in the model.

4.2. Environmental Effectiveness

The overall environmental objective is to prevent the occurrence of excessive nitrogen leaching. Although we don't dispose of a damage function, we can state that consequences of the CPT system and the simpler EPT system are also quite different. The FLA administrative database shows that the CPT policy type has successfully induced a reallocation of manure disposal. Fig. 3 shows the difference in the average municipal nitrogen use per hectare of farmland between the

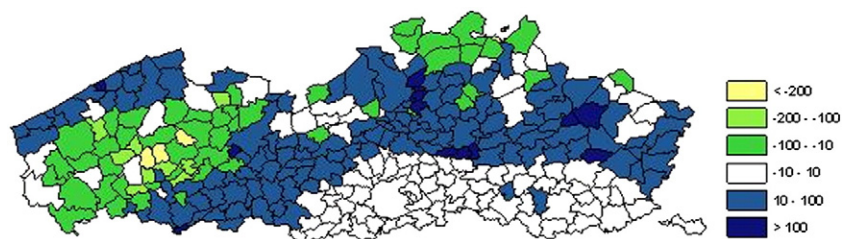


Fig. 3. Difference in average nitrogen use per hectare of land per municipality between CPT and EPT in 2008 (kg N/ha).

Table 1
Simulated manure allocation behaviour under CPT (million kg N), 2008.

	On-land disposal	Own-land disposal	Transport	Processing	Production
Cattle	65.08	57.76	7.32	0	65.08
Pig	33.09	10.95	22.14	10.89	43.98
Poultry	0	0	0	9.94	9.94
Other animals	2.30	1.76	0.54	0	2.30
Total	100.47	70.47	30.00	20.83	121.30

CPT and EPT system. A negative value means a lower average nitrogen use in case of CPT.

The CPT system, since it imposes a lower emission concentration, forces manure to be moved to other locations. Our MP-MAS simulations shows that, under the EPT system, based on the identified land area of 644,000 ha, 422,000 ha (66%) would receive a lower or equal manure emission, whilst 222,000 ha (34%) would receive a higher manure emission compared to the CPT system. The higher manure emission under EPT is observed in the areas that would export under CPT, the lower manure emission in areas with net imports of manure. On 82,000 ha of land (12.7%) the maximum EU nitrogen concentration for vulnerable areas (i.e. 170 kg N from manure/ha) is exceeded more than twice (i.e. more than 340 kg N from manure) under an EPT system.

4.3. Wider Economic Effects: Competitiveness and Distribution

With the EPT system, only agronomical limits constrain farmer's use of manure. To ensure an equal total emission in Flanders for both scenarios we imposed at macro level that emission abatement should be the same under both policies. Simulation of the EPT scenario then shows that practically no manure transport occur, meaning that all disposed manure, originates from the own farm. Simulation of a CPT system (Table 1) shows that farmers become either a supplier or a purchaser of permits, and that permits are indeed traded between farms in these groups.

In 2008, slightly more than 100 million NARs were grandfathered to farmers in Flanders. This allows for the disposal of more than 80% of the total emissions produced (121 million kg N). From this total nitrogen use of 100.5 million kg, almost 30% is spread with traded NARs. Although the NAR market is an important tool enabling the farmer to manage manure emissions and meet legal requirements, the supply of NARs is not sufficient to allow all of the manure to be used on the land. In total, 20.83 million kg N still has to be processed or exported to other countries.

Due to the heterogeneous nitrogen content of manure, allocation behaviour for the four manure types significantly differs. The manure type with the highest nitrogen content will be chosen for the most expensive allocation option. This explains why the processing option is mainly met by using poultry and pork manure. Most of the traded NARs are used for the disposal of pig manure: 74% of the overall NAR trade. Cattle manure is mostly used with a farm's own NARs (89% of the total production) because of the higher transportation costs

where NARs are exchanged, and the fact that cattle farmers usually possess more land per livestock unit than pig or poultry farmers.

The CPT system also leads to regional differences in NAR prices, given the local demand for permits and differential transportation costs. These regional differences are specific to CPT because the permit prices of an EPT with a perfect market should be uniform. The regional difference will of course also have an impact on the regional distributional effects of the policy. Fig. 4 gives evidence for this by showing the differences in total costs for each municipality.

Not only regional distribution effects, also a redistribution between farm types is observed. Especially farms specialised in pig production experience larger costs under CPT (+32% net costs). Specialised poultry and cattle producers experience less net costs (respectively -8% and -2%). The crop producers experience the largest decrease in net costs (from +70 000 Euro to -4.6 million Euro).

Whilst managing the regional dispersal of emissions, the CPT system also provides the policy makers with additional opportunities to protect more vulnerable regions. In the Flemish case, this option is used to further reduce manure concentrations in regions with high values for wildlife or for drinking water resources. This policy option has distributional consequences because farms located in vulnerable zones are affected more than other farms. A voluntary buy-out scheme for permits might alleviate this inequality. This has, for example, been done in the Dutch phosphate EPT system (CPB, 2000), or in the Flemish CPT case. Farms located in vulnerable regions have the option to participate in agri-environmental schemes. In return for a payment, they voluntarily agree to dispose of less manure on their land than the maximum allowed concentration. This system allows the government to buy out NARs in regions with high vulnerability. Although this option exists in Flanders, it is not simulated in our model.

4.4. Dynamic and Soft Effects

CPT gives more incentives for innovative management. A CPT policy introduces additional limits and costs. The effect is threefold. First, as transportation costs are expensive, farmers might reduce manure production by altering stock density or feed composition. Second, manure surplus farmers will try to transport surplus manure as cheap as possible. As long as transportation costs are sufficiently low, NARs can be bought and the manure can be transported. Reducing transportation costs can be achieved by increasing the nutrient content of manure. Third, manure processing becomes an attractive alternative when transportation costs increase, whilst under EPT this would not be considered. All options lead to innovation and the search for efficient techniques.

4.5. Administrative Costs

Administrative and monitoring costs under CPT increase because both the amount of manure and the location of disposal have to be registered. With EPT, administrative costs involve monitoring trade in NARs and nutrients between farms. With CPT, additional tasks include monitoring the location of manure disposal at parcel level. Enforcement

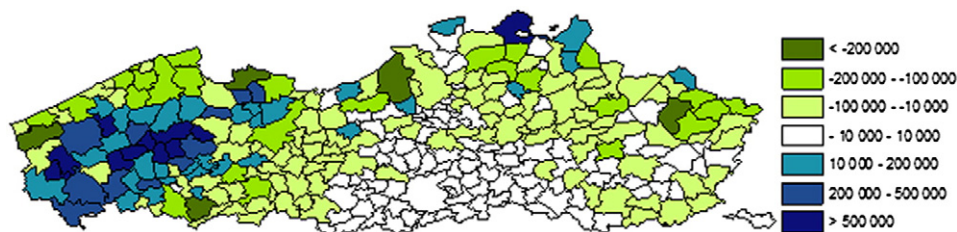


Fig. 4. Difference in net costs per municipality between CPT and EPT in 2008 (Euro).

strategy comprises controlling the manure disposal, using GPS and helicopters.

5. Discussion and Conclusion

Montgomery (1972) has already demonstrated that, theoretically, a competitive market within a tradable concentration permits system would result in the minimisation of total emission control costs, whilst attaining the predetermined environmental standard at each receptor. Stavins (1995) refined this result by incorporating transaction costs in the analysis. He shows that transaction costs may influence market equilibrium in the case of emission permits and that they may impede the implementation of tradable concentration permit systems, despite their theoretical advantages in terms of pollution control.

This paper uses the manure regulation policy in Flanders as a real world example of the application of tradable concentration permits and the use of a multi-agent model allows transportation costs to be considered in the analysis. Using an administrative database of 36,000 firms active in the trade of manure concentration permits, the costs and effectiveness of the CPT policy are compared to a simpler EPT policy alternative. The simulations show that the CPT system outperforms the traditional tradable emission permit system in terms of meeting environmental standards. However, this improved environmental performance comes at the expense of increased manure transportation costs for those farms producing excess emissions. In the Flemish manure case, these extra costs amount to 7.7 million Euros which represents a cost of 400 Euros for each farm with excess emissions.

In the case of manure, the emission is transportable to the location of the concentration permits. More farms get the opportunity to participate in the market for concentration permits, which then creates greater competition. The regional submarkets experience different prices, which are linked to the emission transportation costs. This allows for the generalisation of CPT policies. One important conclusion is that the transportation cost of the emission may be an important reason for the system not often being used as a pollution control option. In the case of air or water toxins, transportation costs are very high. This means that rights can only be transferred to firms within a specific area, resulting in the existence of several small submarkets (Atkinson and Tietenberg, 1987). Another conclusion is that any complete environmental assessment of a CPT system has to include the pollution from transportation since this can be significant.

The distribution of concentration permits in the case of Flemish manure is based on agricultural land. Concentration permits are assigned to each plot based on its size, location and vulnerability to nitrate leaching. The administration costs of assigning concentration permits are currently limited, because today farms are already subject to administrative input for other purposes, such as direct payments from the Common Agricultural Policy. The main additional administrative costs are associated with the exchange of NARs between farms. The different opportunities for transfer of concentration rights are controversial (Tietenberg, 2003). Those who are in favour of the free exchange of permits argue that any restriction reduces the efficiency of the system (Tietenberg, 2003). Yet, others argue that intervention in the free market of rights is justifiable to prevent socially unacceptable outcomes, such as the loss of community interests, environmental degradation and the concentration of rights. Further research may focus on these issues. The conclusion is that a tradable concentration permit system is an adequate policy alternative in a scenario with the following features: a low transportation cost for the emission, transparent distribution of the concentration rights and a market for concentration rights involving many participants.

This research can therefore be seen as putting a theoretical concept into operation, whilst benefitting from existing empirical work, not in the least the modelling that has been done. An approach has been used that combines mathematical programming models of individual

farms with a spatial equilibrium model. This proves to have the potential, not only to simulate trade in permits, but to analyse additional policy interventions.

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