



The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

Combining results of different models: the case of a levy on the Dutch nitrogen surplus

Nico B.P. Polman*, Geert J. Thijssen

*Agricultural Economics and Rural Policy Group, Wageningen University, Hollandseweg 1,
6706 KN Wageningen, The Netherlands*

Received 21 July 1999; received in revised form 28 November 2000; accepted 1 January 2001

Abstract

Economic instruments, such as levies are considered by the Dutch government for reducing the harmful effects of the production and application of manure. To analyse these levies a framework which makes it possible to combine and to choose among different types of research is developed. The results are integrated along the line of the marginal abatement cost curve. The problems related to integrating different types of research are taken into account. The method developed allows every farmer to react to a levy differently. A levy turns out to be more effective to reduce the nitrogen surplus on farm level in the pig fattening sector when compared to the pig breeding sector. But even a levy of 2 guilders/kg of nitrogen does not remove the total manure surplus in the pig sector and results in large profit losses. Further research is needed to underpin the empirical input required by the model. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Marginal abatement cost curve; Regulatory levy; Manure problem; Nitrogen surplus; Pig farms

1. Introduction

An expanding livestock production in The Netherlands has resulted in manure becoming a problematic waste product instead of valuable farm input. The problem is especially acute in the south and east of the country, where specialised intensive pig and poultry farms are concentrated on sandy soils. These farms generally have very little land to grow fodder for livestock, and therefore, the production of livestock is based on imported feedstuffs. The traditional ways to dispose manure on the land have resulted in huge amounts of minerals, such as nitrogen and phosphate, being discharged into the environment, causing serious environmental problems. In an attempt to decrease

the adverse environmental effects from these mineral ‘leakages’ into the ground and atmosphere the Dutch government has developed a manure policy dominated by ‘command and control’ instruments (Dietz, 1992). A levy on the nitrogen surplus is an important instrument in the governmental policy (Ministry of Agriculture, Nature Management and Fisheries, 1995; Ministerie van Landbouw, Natuurbeheer en Visserij, 1997; Eerste Kamer, 2000). From 1998 on, most of the pig farmers have to record all nitrogen inputs (feed, fertiliser, piglets, etc.) and nitrogen outputs (meat, manure, crops, etc.). Based on the resulting sheet a levy is imposed on the difference (positive, above a certain level) between the input and the output of nitrogen. A farmer can choose how to react to a levy: he can reduce the inputs of nitrogen and/or reduce the negative effects from the output of nitrogen by processing or transporting manure to other farms.

* Tel.: +31-317-482097; fax: +31-317-484736.

E-mail address: nico.polman@alg.aae.wau.nl (N.B.P. Polman).

Many quantitative studies have been undertaken to analyse the production behaviour of farmers in relation to a levy on nitrogen. These modelling approaches can, on basis of their methodological approach, be divided in two subgroups: programming models (e.g. Berentsen and Giesen, 1992; Vatn et al., 1997; Lauwers and Huylenbroek, 1997) and econometric models (Burrell, 1989; Vermersch et al., 1993; Fontein et al., 1994; Hertel et al., 1996; Oude Lansink and Peerlings, 1997). Both approaches have their own advantages and disadvantages. In this paper our strategy is somewhat different from the approaches discussed above.

First, a method is developed which makes it possible to combine the results of programming models and econometric models in one framework. A farmer has several options to react to a levy on the nitrogen surplus. To analyse the possibilities of these different options several types of models are used. The results are integrated along the line of a marginal abatement cost curve.

Second, the effects of a regulatory levy on the nitrogen surplus are analysed for Dutch fattening pig farms and Dutch breeding sows farms. Starting point is the development of a relation between the reduction of the nitrogen surplus and the costs per unit of nitrogen reduction for each individual pig farm. The resulting relation is discontinuous and differs per farm. Using this relation the effects of a levy on the nitrogen surplus are analysed with respect to income, nitrogen surplus, and options adopted. We used farm level data from 26 specialised pig fattening farms and 147 pig breeding farms over the period 1987–1989.

The paper is organised as follows. The concept is introduced in Section 2. Our empirical assumptions are described in Section 3. In Section 4, the computer program used is described. The empirical results are presented in Section 5. The paper concludes with comments on this research.

2. The marginal abatement cost curve

Starting point of constructing the marginal abatement cost curve is the assumption that the farmer minimises the sum of the costs of the reduction of nitrogen on the farm and the levies, he has to pay

$$\min_{n_i} \sum_{i=1}^I c_i(n_i) + t(s - \sum_{i=1}^I n_i)$$

subject to $\sum_{i=1}^I n_i \leq s$ and $n_i \leq m_i$ (1)

where n_i is the amount of nitrogen reduction according to option i , m_i the maximum use of option i , c_i the cost of using option i , s the total amount of nitrogen on the farm (in the manure), t the levy on the nitrogen surplus, and I the number of options mentioned.

In this study, every individual farmer has five options to react to a levy on the nitrogen surplus¹ or pay the levy:

1. spread the nitrogen over the land in accordance to government standards;
2. reduce the number of pigs and change the amount of feed within the existing technology;
3. change the technology by using feed containing less nitrogen;
4. transport nitrogen to other farms;
5. transport nitrogen to a processing industry.

Individual farmers react differently on levies depending on their endowments and the relevant prices.

To analyse the possibilities of these different options several models can be used. We use several types of research, depending on the option at hand. The choice for a type of study depends on results that are available.

The marginal abatement costs of option (1) and (5) are derived by straightforward calculations. Option (2), adapting the number of pigs and the amount of feed, is analysed by using an econometric model. Mathematical programming is used for calculating the marginal abatement costs of using feed containing less nitrogen, option (3). An questionnaire is used to analyse the possibilities of transporting of nitrogen to other farms, option (4).

Options (1), (3)–(5) are assumed to have constant marginal costs. A farmer can opt for a definite alternative with a certain maximum, but is not obliged to use the whole alternative. In option (2), a positive linear relationship between marginal costs and nitrogen reduction is assumed, based on the relationship

¹ Options like using less fertiliser or changing cropping patterns are not taken into account, because Dutch specialised pig farms have almost no land available.

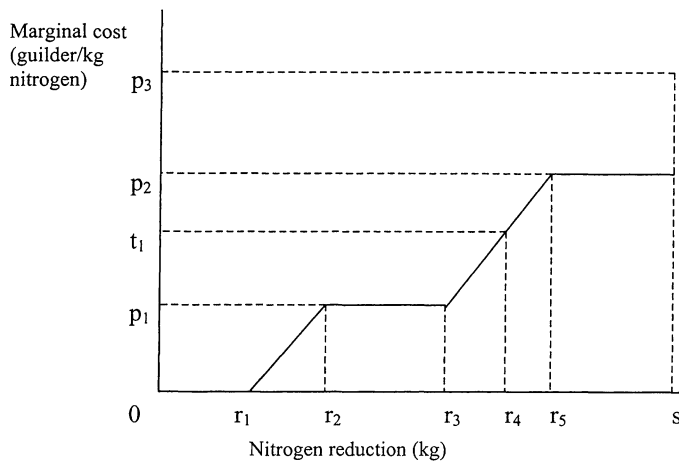


Fig. 1. The relation between the marginal cost and the nitrogen reduction.

of decreasing returns to scale between the output of a pig farm and the nitrogen excretion.²

Fig. 1 gives the marginal abatement cost curve where a levy t_0 is imposed. The farmer has a couple of hectares to which he can apply nitrogen according to the standards without extra cost ($r_1 - 0$). After considering the options, the farmer opts to reduce the number of animals, which reduces his nitrogen surplus by $r_2 - r_1$. He opts for a reduction because its marginal cost is lower than the marginal cost of the alternatives. The next alternative he uses is reducing the nitrogen content of feed at a price p_1 per kilogram nitrogen. He can reduce his surplus by this new technology to a maximum of $r_3 - r_2$. The marginal cost of reducing the nitrogen content of feed is constant. After another reduction of the number of animals, he opts for transporting the manure off the farm at a price p_2 per kilogram nitrogen. The total amount of this farmer's surplus is equal to s , therefore, the amount of nitrogen transported is equal to $s - r_5$. The fifth option (processing) is not relevant for this farmer because of its high marginal cost.

A farmer confronted with a levy t_1 on the nitrogen surplus will reduce the amount of nitrogen by r_4 , where the marginal cost of nitrogen reduction is equal to the levy. The farmer puts $(r_1 - 0)$ nitrogen on his land, in accordance with the permitted standards. He

reduces the amount of nitrogen produced by reducing the number of pigs by $(r_2 - r_1) + (r_4 - r_3)$. Reducing the mineral content of feed results in a nitrogen reduction of $(r_3 - r_2)$. He pays a levy on $(s - r_4)$. This part of the N excreted by the livestock will cause environmental damage, but for this farmer it is cheaper to pay a levy than to reduce the nitrogen surplus by $(s - r_4)$.

For the options (1), (3)–(5), linear (or even non-linear) relations between marginal abatement costs and the nitrogen reduction can be assumed. The assumptions in this research are made because of available models: they are not necessary for our integrating approach. With respect to the reduction of the number of animals, it is also possible to assume constant marginal abatement costs. A consequence is that a farmer will not reduce the number of animals one by one, but only reduce the total stock at one go.

3. Empirical input to the model

A farmer has five options for dealing with the total amount of nitrogen on the farm. The marginal cost and the maximal use a farmer can make of an option for the year 2000 are based on several studies. Table 1 gives a summary of the marginal cost and maximal use on farm level for fattening and breeding pigs.

According to Table 1 farmers can apply nitrogen on their land without cost. Farmers will do this even without a levy, therefore, the cost of spreading manure

² This relationship between the good output and the bad output is in line with Coggins and Swinton (1996).

Table 1

Assumptions of cost and maxima of different options for reducing the amount of nitrogen on farm level for fattening and breeding pigs in the year 2000^a

No.	Option	Cost (guilders/kg nitrogen)		Maxima (% nitrogen)	
		Fattening	Breeding	Fattening	Breeding
1	Land application	0	0	300 kg per hectare	300 kg per hectare
2	Pigs reduction	Variable ^b	Variable ^b	0–100	0–100
3	Feed containing	0.45 ^c	2.193	16	3
4	Transportation	1.23 or 1.71 ^d	–	7.9	–
5	Processing	2.63	4.62	15.5	15.5

^a Except processing: 1995.

^b Depends on the number of pigs reduced.

^c Average, depends on the amount of feed used.

^d The amount 1.23 for the provinces Gelderland, Utrecht and Overijssel; 1.71 for the provinces Limburg and Noord-Brabant because of the transporting distance.

is ignored. The maximum amount of nitrogen that a farmer may apply on the land consists of two parts: acceptable loss plus uptake by the crop. The calculated norm for acceptable losses from the soil is based on different assumptions concerning acceptable standards for the environment. According to Zeijts et al. (1993) 136 kg nitrogen per hectare is the norm for acceptable losses that can be applied. Zeijts et al. (1993) use straightforward calculations. It is assumed that the only crop a farmer grows is fodder maize, which gives the amount of nitrogen that is removed per hectare, 170 kg nitrogen per hectare.³ So, no levy is charged for 306 kg nitrogen per hectare; for simplicity, this figure was rounded down in the calculations to 300 kg per hectare.

Reducing the number of pigs and changing the amount of feed within the existing technology is analysed by Fontein et al. (1994) by means of an econometric model. Using data on Dutch pig farms over the period 1975–1989 they take nitrogen excretion into account and assume that the nitrogen excretion is proportional to the number of pigs. A levy on the surplus of nitrogen results in a reduction of the number of pigs, a decrease in the feed input and a decrease in the output of meat. Therefore, profits (the difference between revenue from meat and the

costs of pigs and feed) will decrease. In our study, we call this profit loss the costs of option (2). The linear coefficient between marginal abatement costs and nitrogen reduction turned out to be 0.000243 (with a *t*-value of 4.43) for pig fattening farms and 0.0004660 (with a *t*-value of 4.81) for pig breeding farms. This means that increasing the nitrogen reduction by 1 kg leads to an increase of 0.000243 guilders in the costs for pig fattening farms. Reducing the number of animals is about twice as expensive for a pig breeding farm when compared to a pig fattening farm.

Excretion of nitrogen depends largely on the input of nitrogen by feed. Dutch pigs are fed almost exclusively on compound feed that comes from outside the farm (Wijnands et al., 1992). The nitrogen content could be modified in several ways, such as matching the compound feed to the nutrient needs of the animals better, stage feeding and the addition of phytase. Improvement of the feed conversion will also reduce the nitrogen excreted (TNO/Heidemij, 1992). We obtained data about the costs and effects of feed containing less nitrogen from a study (mathematical programming) by Baltussen and Horne (1992). For the pig breeding sector Baltussen and Horne (1992) found that a change of the nitrogen input in feed of –3% would lead to a change in cost of feed of +0.2% and a decrease of the nitrogen excretion of 3%. For the pig fattening sector, these figures are, respectively, –11, +0.3 and 16%. Combining these figures with the feed costs on the farms in the sample resulted in the averages presented in Table 1.

³ One kilogram of fodder maize removed from a farm, contains 13.6 g nitrogen/kg of dry weight (CBS, 1992). In The Netherlands, the mean yield of fodder maize was 12500 kg of dry weight per hectare in the period 1987–1989 (LEI-DLO/CBS, 1992). Multiplying yield per hectare by the nitrogen content per kilogram gives 170 kg nitrogen per hectare.

The transportation of manure to farms with a manure shortage becomes more important when the norms for manure spreading are sharpened. Opportunities for transporting nitrogen elsewhere in the region will decrease, because the tightening of the norms in the near future will mean that dairy farms are also confronted with severe constraints on manure disposal. In this study, we assumed that the possibilities of transporting manure to other farmers in the same region no longer exist. The only option open is to transport manure to regions that are short of manure. The possibilities of transporting manure from pig breeding are limited because of the disadvantages of this type: 70% of the arable farmers do not wish to have manure from pig-breeding farms and the remaining farmers rate this manure very low (Baltussen et al., 1993). The study of Baltussen et al. (1993) is based on a questionnaire. We assumed that no manure would be transported from pig breeding farms. The transportation of manure from the pig fattening sector remains possible. It is assumed that each pig fattening farm can transport the same proportion (7.9%) of its excreted nitrogen.⁴

The cost of transporting manure varies with province and is taken from data of the Stichting Landelijke Mestbank (National Manure Bank). We used the prices without premiums for quality. This results in a price of 1.23 guilders/kg nitrogen for the provinces of Gelderland, Utrecht and Overijssel and 1.71 guilders/kg nitrogen for the provinces of Limburg and Noord-Brabant (Ministerie van Landbouw, Natuurbeheer en Visserij, 1993).

The future capacity of manure processing is unclear because of uncertainties about the market for the product of manure processing and about a guaranteed supply, and the high cost involved (Berghs, 1993). There were concrete projects for processing 3 million tonnes manure per year in the period until 1995

(Tweede, 1993).⁵ The total production is 19.4 million tonnes manure per year for the entire pig sector in The Netherlands. This means that every farmer can process 15.5% of the nitrogen excreted by his pigs. The cost of manure processing is based on assumptions made in other studies. The CLM (Centre for Agriculture and Environment) (Zeijs et al., 1993), TNO/Heidemij (1992), Os and Baltussen (1992) calculated a price of approximately 30 guilders, we used this price in our study.

The emission of ammonia is important because nitrogen is a constituent of ammonia. The amount of ammonia emitted depends mainly on the species of animal and the type of livestock housing. In intensive pig farming, the pigs are kept indoors, and therefore, the emission from the pig shed is paramount.⁶ In our study, a farmer pays a surplus levy on the nitrogen excretion that is emitted via ammonia from the pig shed.

4. Calculations and data

The data used in this study are from a sample of Dutch farms that keep accounts of their farming for the Agricultural Economics Research Institute. Annual data from 26 specialised pig fattening farms and 147 pig breeding farms over the period 1987–1989 are used. The calculations were made with one input feedstuff, covering 90% of the feed cost. The average nitrogen output on pig fattening farms is more than twice the amount of excreted nitrogen on the breeding sows farms. The mean surpluses per hectare in the fattening and breeding sector were successively approximately 2300 kg nitrogen per hectare and 1200 kg nitrogen per hectare.⁷

A program is developed to carry out the calculations. Fig. 2 gives a schematic overview of the calculation program for pig breeding farms, the same structure is used for the pig fattening farms.

⁴ As a result of the mineral bookkeeping and the price of manure, the volume of manure supplied to the arable farming sector will decrease by about 35% (Baltussen et al., 1993). In 1990, roughly 1.3 million tonnes of manure was transported to the arable regions. This will decrease to no more than 850 thousand tonnes. The total production of manure on pig fattening farms was 10.8 million tonnes (Mulder and Poppe, 1993), and therefore, a farmer is able to transport 7.9% of the nitrogen excreted by his pigs (850 thousand tonnes/10.8 million tonnes).

⁵ Straightforward calculations.

⁶ We assumed that each farmer has a conventional pig shed, with an average ammonia emission. In the conventional pig shed (see Monteny, 1991) the amount of excreted nitrogen that disappears as ammonia emission is equal 21% for pig fattening farms and 16% for pig breeding farms.

⁷ In this period, transportation of manure to other regions was not important. Nowadays transportation of manure already takes an important share of total manure production.

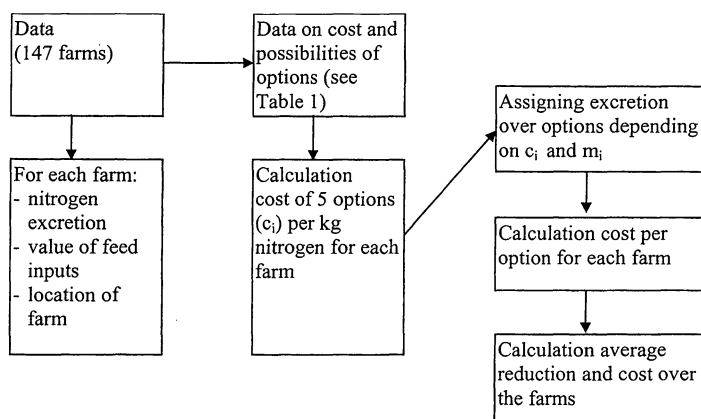


Fig. 2. Schematic overview of calculation program for pig breeding farms.

The program consists of several parts and is built up as follows:

- The program selects from the original data set of 147 pig breeding farms for each farm the nitrogen excretion, location of the farm and, the value of feed inputs.
- The program calculates for each farm the marginal abatement costs for every option.
- The assignment of nitrogen excretion over the different options. The program allots a part of the nitrogen excretion (we used a step of 25 kg nitrogen) to an option with the lowest marginal costs. If there is any nitrogen left, the program again looks for the cheapest way to reduce the nitrogen surplus by 25 kg nitrogen. At the end of this part there is a vector containing the cost of reducing the nitrogen surplus for every farm and every 25 kg excreted (for the first 25 kg, the second 25 kg and so on until the last 25 kg reduction).
- The program calculates the amount of nitrogen and the cost per option per farm, on basis of the constructed marginal abatement cost curve in the previous steps. The results are summed and the average is calculated in the last part.

5. Results

For every farm the consequences of different levies (0, 1, 1.5, etc.) were calculated using the calculation program. Figs. 3 and 4 show the consequences of a

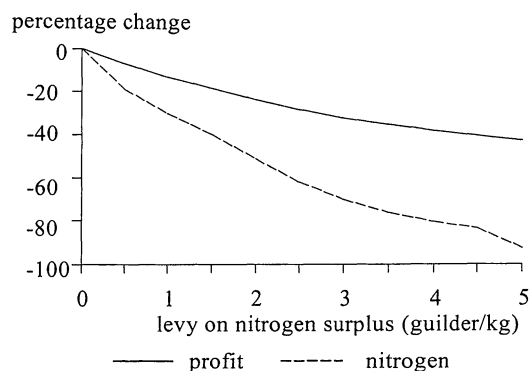


Fig. 3. Change of profit and surplus (exclusive ammonia emission and manure applied on the land), for different levies, average for pig breeding farms.

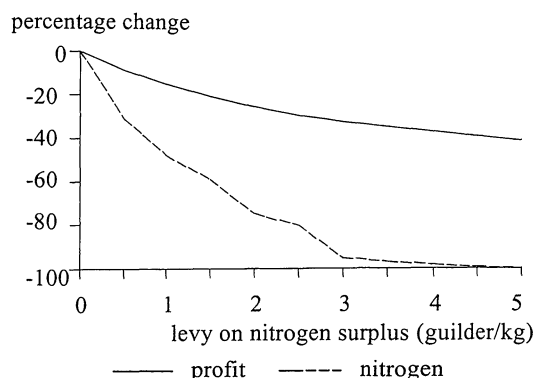


Fig. 4. Change of profit and surplus (exclusive ammonia emission and manure applied on the land), for different levies, average for pig fattening farms.

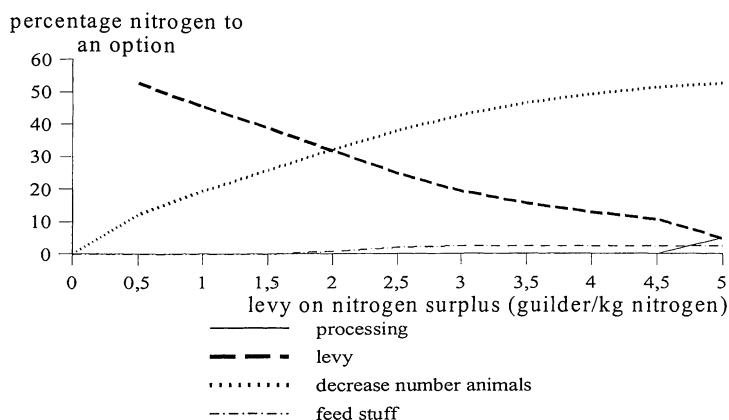


Fig. 5. Reaction of farmers to different levels of a levy for an average pig breeding farm.

levy on profit and nitrogen surplus in the Dutch pig sector.

A levy solving the environmental problems resulting from the nitrogen excretion results in a profit loss of roughly 42% for an average pig fattening farmer. A levy of 5 guilders leads to a profit loss of 44% and an almost 95% reduction of the environmental damage of nitrogen resulting from the pig breeding sector.

A 70% reduction of the nitrogen surplus will be achieved by a levy of 3 guilders in the pig breeding sector, whereas almost the same reduction (75%) in the pig fattening sector is already achieved by a levy of about 2 guilders. The reason for this is that the marginal costs of the alternatives are lower for the pig fattening sector than for the pig breeding sector.

Note that, a levy has to be paid for the nitrogen emitted via ammonia, but the nitrogen legislation is not intended to reduce the environmental damage resulting from such an emission. The reason for extra legislation for the ammonia emission is that the marginal costs of reducing the nitrogen surplus via a reduction of the ammonia emission is too high to regulate with one levy on the nitrogen surplus (Tweede, 1993).

An overview of the adaptation of the different options by the farmers in the pig breeding and pig fattening sector to different levels of levies is given in Figs. 5 and 6. Nitrogen excretion emitted via the ammonia emission from the pig shed and the application of manure are not given because they are constant and not depending on the height of the levy.

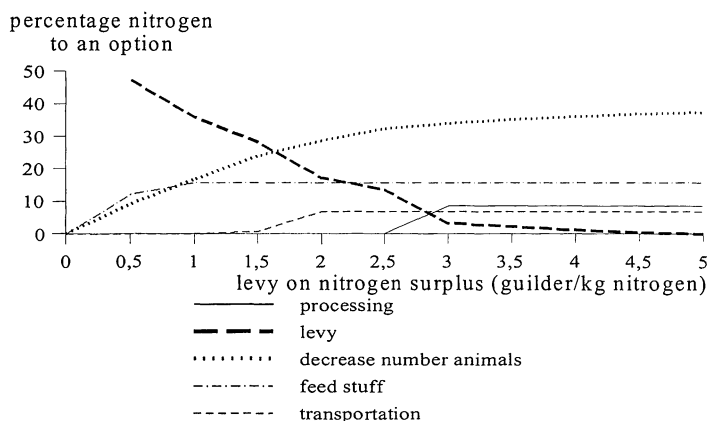


Fig. 6. Reaction of farmers to different levels of a levy for an average pig fattening farm.

When the levy rises farmers pay a levy over a decreasing part of the nitrogen excretion. Farmers will not pay the high levies because these levies exceed the marginal cost of their options for reducing the nitrogen surplus. For both sectors the options differ in their marginal cost and availability.

Compared with a pig fattening farmer, the average pig breeding farmer uses fewer alternatives to reduce his nitrogen surplus at farm level. From Figs. 5 and 6, it is clear that the possibilities of processing manure and using feed containing less nitrogen are limited in the pig breeding sector. The largest part of the reduction of the surplus comes from reducing the number of animals. The pig breeding sector will reduce the number of pigs more than the pig fattening sector: more than 50% by a levy of 5 guilders, compared with no more than 40%. This is because the average pig fattening farmer has more options available than a pig breeding farmer and these options are less expensive.

6. Conclusions and discussion

A levy on the nitrogen surplus in the Dutch pig sector is analysed by integrating different types of research into one framework. The method we used allows each farmer to react differently to a levy on the nitrogen surplus. A farmer can react by spreading nitrogen over the land, reducing the number of animals, using feed containing less nitrogen, transporting manure to other farmers, processing manure or paying a levy. We calculated a marginal abatement cost curve for each farm. The minimal costs of reducing the nitrogen surplus were calculated for different levies.

Farmers in the pig fattening sector have more options for reducing their nitrogen surplus than farmers in the pig breeding sector. In addition, the marginal costs of the options are lower in the pig fattening sector. Levies are more effective in this sector because they achieve higher reductions of the nitrogen surplus compared to the pig breeding sector. A reduction of the nitrogen surplus of approximately 51% can already be reached with a levy of 1 guilder for an average pig fattening farm, whereas almost the same reduction (48%) in the pig breeding sector requires a levy of 2 guilders.

The loss of profit caused by the reduction in nitrogen differs less between the pig fattening sector and the pig

breeding sector than the reduction of nitrogen output. In the latter sector a reduction of about 70% will be achieved with a loss of profit of 33%. The same profit loss in the pig fattening sector leads to a 75% reduction in surplus nitrogen.

Several aspects of integrating different types of research could be improved:

1. Differences in objective function. The econometric model is based on neo-classical theory and on the past. Linear programming models (and also straightforward calculations) use a normative approach.
2. Technology differences per study used (econometric studies versus linear programming models).
3. The differences between analysis at farm level compared to analyses at level of the sector. Variables that are exogenous at the micro level may be endogenous at the meso or macro level.
4. Changes in government policy. The intended Dutch manure policy has changed more than once in the past 15 years. Based on government policy, different studies use different definitions, different policy simulations, etc.

The framework developed makes it also possible to take other assumptions into account. For example, it is assumed that manure transportation is impossible in the pig breeding sector, but it could be possible that in the future with fewer animals (equals to less manure) there will be opportunities for farmers in that sector to transport manure. Also more variation in transport cost and different possibilities for manure processing could be incorporated.

The method uses the same possibilities and prices for all farms for the options processing manure, reduction in the number of pigs and land application (slurry spreading). Prices and possibilities are differentiated more for the option "less nitrogen in feedstuff and the cost of transportation" and could be differentiated more for the other options.

In the real world, a farmer has more options than those investigated in this research. It is conceivable that because of technical developments a farmer will have more options in the future to do something about his manure problem than is presently the case. Another aspect that could be incorporated is the mathematical incorporation of dynamical aspects and sectoral effects. Also further research is

needed to underpin the empirical input required by the model.

Acknowledgements

The authors wish to thank A. Oskam and L. Lauwers for helpful comments on an earlier draft. The willingness of the Agricultural Economics Research Institute in The Hague to make data available for this study is gratefully acknowledged.

References

- Baltussen, W.H.M., van Horne, P.L.M., 1992. Effect van stikstofheffingen op de voersamenstellingen in de intensieve veehouderij. Landbouw-Economisch Instituut (LEI-DLO), Mededeling 475, Den Haag.
- Baltussen, W.H.M., van Gaasbeek, A.F., Daatselaar, C.H.G., 1993. Marktonderzoek naar binnenlandse afzet van dierlijke mest. Landbouw-Economisch Instituut (LEI-DLO), Publikatie 3.155 Den Haag.
- Berentsen, P.B.M., Giesen, G.W.J., 1992. An economic evaluation of various governmental policies to reduce N-losses in dairy farming. In: Heijman, W.J.M., Krabbe, J.J. (Eds.), *Issues of Environmental Economic Policy*, No. 24. Wageningen Economic Studies, Wageningen, pp. 169–184.
- Berghs, M., 1993. De mestoverschottenproblematiek in 1995 en 2000: wat betekent dit voor de varkenshouderij? *Info-Bull. Varkenshouderij* 1, 32–38.
- Burrell, A., 1989. The demand for fertiliser in the United Kingdom. *J. Agric. Eco.* 40, 1–20.
- CBS, Centraal Bureau voor de Statistiek, 1992. Mineralen in de landbouw, 1970–1990. Voorburg/Heerlen.
- Coggins, J.S., Swinton, J.R., 1996. The price of pollution: a dual approach to valuing SO₂ allowances. *J. Environ. Eco. Manage.* 30, 58–72.
- Dietz, F.J., 1992. The economics and politics of the Dutch manure problem. *Environ. Politics* 1, 347–382.
- Eerste Kamer (First Chamber Dutch Parliament) 2000. Wijziging van de Meststoffenwet in verband met een aanscherping van de nomren van het stelsel van regulerende mineralenheffingen, vergaderjaar 2000–2001, nr. 23.
- Fontein, P.F., Thijssen, G.J., Magnus, J.R., Dijk, J., 1994. On levies to reduce the nitrogen surplus: the case of Dutch pig farms. *Environ. Resource Eco.* 4, 455–478.
- Hertel, T.W., Stiegert, K., Vroomen, H., 1996. Nitrogen-land substitution in corn production: a reconciliation of aggregate and firm-level evidence. *Am. J. Agric. Eco.* 78, 30–40.
- LEI-DLO/CBS (Landbouw-Economisch Instituut and Centraal Bureau voor de Statistiek), 1992. Landbouwcijfers 1992. Voorburg/Heerlen.
- Lauwers, L., van Huylenbroek, G., 1997. Cost effectiveness of social corrections in Flemish manure disposal regulation. *Tijdschrift voor sociaal wetenschappelijk onderzoek van de landbouw (TSL)* 12, 58–72.
- Ministry of Agriculture, Nature Management and Fisheries, 1995. Policy document on manure and ammonia. Den Haag, pp. 38.
- Ministerie van Landbouw, Natuurbeheer en Visserij, 1993. Wijziging Reglement Mestbank inzake vangnetfunctie en kwaliteitspremiëringssysteem. *Staatscourant* 250, pp. 23.
- Ministerie van Landbouw, Natuurbeheer en Visserij, 1997. Wijziging Meststoffenwet. *Staatsblad* 1997, 360 (Inwerkingstredings-KB: besluit van 15 December 1997).
- Monteny, G.J., 1991. Stand van zaken onderzoek vermindering NH₃-emissie: perspectieven voor de toekomst. In: Verkerk, H.A.C. (Ed.), *Mest & Milieu in 2000; Visie vanuit het landbouwkundig onderzoek. Onderzoek inzake de mest—en ammoniakproblematiek in de veehouderij* 13, Veenendaal, pp. 91–113.
- Mulder, M., Poppe, K.J. (eds.), 1993. Landbouw, milieu en economie. Proeve van een periodiek rapportage voor monitoring. Landbouw Economisch Instituut (LEI-DLO), Periodieke Rapportage. Den Haag, pp. 69–89.
- Os, J., van Baltussen, W.H.M., 1992. Gevolgen van milieumaatregelen voor de continuïteit van veehouderijbedrijven. Landbouw Economisch Instituut (LEI-DLO), Publikatie 3.150, Den Haag.
- Oude Lansink, A., Peerlings, J., 1997. Effects of N-surplus: combining technical and historical information. *Eur. Rev. Agric. Eco.* 24, 231–247.
- TNO/Heidemij Adviesbureau, 1992. TNO/Heidemij Adviesbureau, 1992. De Mestoverschottenproblematiek in 1995 en 2000. Een studie ter ondersteuning van de evaluatie van het mestbeleid.
- Tweede Kamer (Second Chamber Dutch Parliament), 1993a. Mestactieprogramma. Notitie mest—ammoniakbeleid derde fase. Vergaderjaar 1993–1994, 19882, nr. 34.
- Tweede Kamer (Second Chamber Dutch Parliament), 1993b. Mestactieprogramma. Lijst van vragen en antwoorden. Vergaderjaar 1993–1994, 19882, nr. 35.
- Vatn, A.L.R.B., Lundebj, H., Romstad, E., Rørstad, P.K.R., Vold, A., 1997. Regulating nonpoint-source pollution from agriculture: an integrated modelling analysis. *Eur. Rev. Agric. Eco.* 24, 207–209.
- Vermersch, D., Bonniex, F., Rainelli, P., 1993. Abatement of agricultural pollution and economic incentives: the case of intensive livestock farming in France. *Environ. Resource Eco.* 3, 285–296.
- Wijnands, J.H.M., Baltussen, W.H.M., Os, J., van Oudendag, D.A., 1992. Ammonia emission in the Dutch livestock sector: abatement possibilities and costs. *Tijdschrift voor sociaal wetenschappelijk onderzoek van de landbouw* 7 (TSL), pp. 321–342.
- Zeijts, H., van Biewinga E.E., Joosten, L.T.A., 1993. Regulerende heffingen en premies op mineralen overschotten van land—en tuinbouw. Onderzoek naar een optimale invulling. Centre for Agriculture and Environment (CLM), CLM 110–1993, Utrecht.

