Plant species protection contracts: modelling contract choice for specialised dairy farms and mixed dairy pig fattening farms in the Netherlands

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Abstract

Proposals of the European Commission stress the future importance of agri-environmental payments within the rural development policy of the European Union. The aim of this paper is to present and discuss a model for choice for plant species protection contracts in the Netherlands. The model includes transaction costs, time and the possibility of lock-in situations related to contract choice. The approach discussed is flexible because it makes it possible to introduce all kinds of technical and institutional restrictions (differences in contract design).

Keywords: agri-environmental contracts, contract choice
JEL classification: C61, L14, Q12, Q24

1 Introduction

Proposals of the European Commission stress the future importance of agri-environmental payments within the rural development policy of the European Union (EC, 2004a). The new policy will replace EC 1257/99 by new support schemes (EC, 2004b). The proposed reform is aced around three major policy objectives: (1) increasing the competitiveness of the agricultural and forestry sector; (2) enhancing the environment and countryside and (3) enhancing the quality of life in rural areas. A total EU funding € 13 billion per year is proposed for the regulation period 2007-2013. Agri-environmental schemes become part of axis 2 (EC, 2004a)[1]. Activities under axis 2 contribute to sustainable rural development by encouraging the main actors (farmers, foresters) to keep up land management in view of preserving and enhancing the natural space and landscape, of protecting and improving the environmental resources and of ensuring the sustainability of use of forestry resources. The policy is meant to reinforce rural development policy and to simplify its implementation.

Policy makers aiming at improving wildlife and landscape have an interest in the reasons why farms choose a specific wildlife and landscape services contract (agri-environmental scheme) in order to design optimal contracts. Several studies apply principal-agent theory to analyse the design of agri-environmental schemes focussing on hidden information and hidden actions (e.g. Ozanne et al., 2001 and White, 2002). Other studies focus on the characteristics of farms and farmers that conclude agri-environmental contracts of uniform design, e.g. Crabtree et al. (1998); Beedel (2000); Wenum (2002); and Wynn et al. (2001). Few studies concentrate on the actual modelling of contract choice as a decision related to other farming activities. Van Huylenbroeck et al. (2000) developed a simulation model to evaluate the impact of agri-environmental programmes on production, management and economic results of dairy farms. However, they do not take into account elements relevant for contract design like contract duration and private transaction costs (costs of negotiation, contracting and control). Peerlings and Polman (2004) use a micro econometric model to model wildlife and landscape contract choice. In their study they take into account transaction costs involved in contract choice but they ignore the elements of time or contract duration and lock-in situations in case of contract renewal. The latter are relevant given that most contracts have to be concluded for a limited number of years. Standard for agri-environmental schemes in the Netherlands is six years. This makes e.g. that under changing conditions a selected contract still has to be fulfilled although it could be not profitable anymore or other contracts would result in higher profits. This means that farms are locked-in in producing wildlife and landscape services due to contract terms or specific investments.

In the Netherlands, about six agri-environmental schemes focus on the protection of plant species on grassland and apply to whole fields (botanical agreements). These contracts prescribe a number of different plant species at the start and or the end of the contracting period. Other prescriptions within the agreements are related to grazing and the use of fertilisers and manure. Kleijn et al. (2004) argue that factors not addressed in the contracts like groundwater levels and regional sewage patterns, in other words grassland quality, may have an overriding influence on the number plant species. Therefore there may be a strong effect of grassland quality on the decision of farms whether or not to conclude a plant species protection contract.

[1] Axis 1: competitiveness and Axis 3 the wider rural economy

The aim of this paper is to present and discuss a model for choosing between different agri-environmental schemes (AES) focussing on the protection of plant species. The model includes transaction costs, time and the possibility of lock-in situations. The model is applied for the choice of individual Dutch farms whether or not to select a plant species protection contract. Data is used from a mail survey (December 2004) among dairy farms in the Achterhoek. The Achterhoek is a region in the eastern part of the Netherlands and is characterised by sand soils. Sand, clay and peat soils cover about 50, 40 and 10% of the Netherlands, respectively (Schröder et al., 2005: 5). More than half of the specialised dairy farms in the Netherlands are located on sandy soil where environmental problems are highest (Berentsen, 2003: 186). The dairy farms in the Achterhoek are representative for these dairy farms.

We start with a discussion of the theoretical model in section 3. Section 4 presents the empirical model and data. Section 5 presents and discusses the results of simulations that highlight the role of transaction costs, manure policies and lock-in situations. The paper concludes with a summary and conclusions.

3 Theoretical model

3.1 Introduction

This section presents a theoretical model of contract choice. Farms will choose to contract or to renew a contract if the expected gains from doing so are greater than those of organising the transaction in some other way (cf. Masten and Saussier, 2002; cf. Masten, 1996), or formally,

$$\begin{aligned} G^* &= G^i, \quad if \quad V^i > V^J, \; and \\ &= G^j, \quad if \quad V^i \le V^J \end{aligned} \qquad (1)$$

where: G^i represents contract i; G^j contract j; V^i and V^j (the farms beliefs about) the corresponding benefits of contract *i* and alternative *j*; G^* represents the contract actually chosen.

V^i and V^j are profits under contract *i* and *j* respectively and determined assuming profit maximisation on farm level. The basic idea is to see alternative contracts as sets of different technologies and transaction costs. Farms pick out that set or contract that gives the highest expected farm profit. Technology is interpreted here as different sets of technical and institutional restrictions. The institutional restrictions follow from the prescriptions in the contract, e.g. a reduction in stocking densities, the cessation of fertiliser input or the presences of a number of bird species per hectare.

3.2 Static model with transaction costs

Suppose farm h maximises profit given a specific technology. Where profit is defined as the difference between revenue of selling outputs (possibly including wildlife and landscape services) and costs of variable inputs (e.g. feed). We assume input and output prices equal between farms although this is not necessary. The price received for wildlife and landscape services is assumed to be contract dependent. The farm is confronted with transaction costs (see for example Falconer et al., 2001 or Van Huylenbroeck et al., 2004). First, there are variable transaction costs that are linked to the production level of wildlife and landscape services (e.g. monitoring). Second, there are fixed transaction costs that are linked to a specific contract choice (e.g. zero if farms do not consider contracting and stay in the initial situation). Examples of fixed transactions costs are search costs and costs to conclude a specific contract. It is assumed here that transaction costs are farm and contract specific. Profit for each specific contract equals:

$$\begin{aligned} &\pi_{hc}(p, p_c^n, w, z_h, t_{hc}, TC_{hc}) = \\ &\quad \max_{y_{hc}, y_{hc}^n, x_{hc}} \left\{ p.y_{hc} + p_c^n.y_{hc}^n - w.x_{hc} - t_{hc}.y_{hc}^n - TC_{hc} \mid T_{hc}(z_h, y_{hc}, y_{hc}^n, x_{hc}); w, p, p_c^n > 0 \right\} \end{aligned}$$

h = 1,…,H and c =1,…,C (2)

where: π_{hc} profit for farm h using contract c; *p* vector of prices of outputs, y_{hc} vector of outputs for farm h using contract c, p^n_c price of wildlife and landscape services using contract c, y^n_{hc} production of wildlife and landscape services production using contract c, x_{hc} vector of variable inputs for farm h using contract c, *w* vector of prices of variable inputs, t_{hc} variable fixed transaction costs for farm h using contract c; TC_{hc} fixed transaction costs for farm h using contract c, z_h vector of quasi-fixed inputs (or outputs) for farm h, T_{hc} technology set for farm h using contract c.

In this static model each contract implies a different technology set, transaction costs and price of wildlife and landscape services. Not choosing a specific contract is of course also an option. The farm just picks out the contract that gives the highest profit. Notice that the variable transaction costs will influence the marginal costs, and therefore, the production level of wildlife and landscape services. They reduce the price received for wildlife and landscape services. The fixed transaction costs do not influence marginal costs but do influence the decision whether or not to produce wildlife and landscape services under a specific contract because they directly affect profit levels.

Lock-in situations can be described with this model when the farm picked out a contract in period 1 and faces the decision to conclude the contract again in period 2. If conditions are less favourable it could be that because extra costs are involved, e.g. grassland renewal, the contract will be concluded again, although, without these extra costs this would not have happened.

4 Empirical model and data

The model of Section 3 is applied in this section for the choice of individual Dutch farms whether or not to select a plant species protection contract. This section also describes the data used in the calculations.

4.1 Empirical model

The theoretical model requires calculation of profits for different contracts. This can be done using a linear programming model. Advantage of this type of model is that not a complete data set of an individual farm and contract is needed if it is assumed that variables omitted are not restrictive or already optimally applied. Moreover, it is relatively easy to formulate technical and institutional restrictions explicitly.

Suppose we have a specialised dairy farm or mixed dairy pig fattening farm that faces the choice whether or not to conclude a plant species protection contract and if a contract is concluded for how many hectares. We assume the number of pigs fixed and that all the pig feed is bought. This is the common situation in the Netherlands where pig feed (concentrates) is bought from the specialised compound feed industry. The farm has given its milk quota and dairy cattle stock a certain fixed feed requirement. It is assumed that farms can either buy this feed or produce it on farm. If less feed is produced than it can buy feed (e.g. concentrates) at a fixed price. Total feed production on the farm is determined by the feed production per hectare. If the farm concludes a plant species protection contract the feed production per hectare will be reduced given the constraints put on e.g. mowing grass. We assume there are three types of grassland, there is good quality grassland (i=1), medium quality grassland (i=2) and bad quality grassland (i=3). These types of land can have a different maximum feed production per hectare. Farms also grow fodder maize on their land. Another effect of concluding a plant species protection contract is that no manure can be applied on land. This can lead to an extra surplus of nitrogen from manure that has to be exported off-farm as a result of Dutch manure policies. This increases costs and makes concluding a plant species protection contract less attractive.

These assumptions are in line with Dupraz et al. (2003). According to Dupraz, et al. (2003) production potential and livestock density of the farm have a negative influence on the participation probability, while the share of low productivity meadows on the farms has a positive influence. Wynn et al. (2001) also find that farms with more productive land have fewer opportunities to enter a scheme and face higher opportunity costs from entry, at least for some elements of agri-environmental measures.

If the contract is concluded the farm receives a fixed price per hectare contracted. The farm maximises the differences between revenue from wildlife and landscape services production minus the costs of feed bought and nitrogen disposal costs by determining the optimal number of hectares of the three types of land contracted, the amount of feed bought and the amount of manure disposal. A higher price of wildlife and landscape services, a lower price of feed and lower costs of nitrogen disposal per unit make contracting more attractive. So:

Objective function:

$$\max_{z_n^i, x_f, x_s, x_c} \quad \pi = p_n \sum_{i=1}^{3} z_n^i - w_f x_f - w_s x_s - w_c x_c \tag{3}$$

Constraints:

$$x_f = feed - \sum_{i=1}^{3} fz_n^i z_n^i - \sum_{i=1}^{3} fz_r^i z_r^i - fz_m z_m \tag{4}$$

$$z^i = z_n^i + z_r^i \qquad \forall i \tag{5}$$

$$x_s = N - a_r \sum_{i=1}^{3} z_r^i - a_n \sum_{i=1}^{3} z_n^i - a_m z_m \tag{6}$$

$$x_c = fert^i \times \sum_{i=1}^{3} z_r^i \tag{7}$$

$$fz_r^i = fz_r^i(fert^i, a_r, z_r^i) \tag{8}$$

$$fz_n^i = fz_n^i(a_n, z_n^i) \tag{9}$$

$$a_r = 250; \quad a_n = 0; \quad a_m = 155 \tag{10}$$

$$0 \le fert^i \le 148 \tag{11}$$

Non-negativity constraints: $z_r^i \ge 0; \quad z_n^i \ge 0 \qquad \forall i$ (12)

where: π profit, p_n price of wildlife and landscape services per hectare contracted, w_f price of bought feed, x_f bought feed, w_s costs of nitrogen removal, x_s nitrogen surplus of manure, w_s price of fertiliser, x_c fertiliser use, *feed* total feed required, fz_n feed production per hectare with wildlife and landscape services production, fz_r^i feed production per hectare without wildlife and landscape services production on land type i (= regular land-use) , fz_m feed production per hectare with maize, z^i total availability of land type i, z_r^i land of type i without wildlife and landscape services, z_n^i land of type i with wildlife and landscape services production, z_m land with fodder maize, N net nitrogen production from animal manure[2], a_r nitrogen application via manure per hectare without wildlife and landscape services production , a_n nitrogen application via manure per hectare with wildlife and landscape services production, a_m nitrogen application via manure per hectare with maize, $fert^i$ fertiliser use per hectare of land type i.

Nitrogen production depends mainly on the number of animals and production level. It is assumed fixed per farm. In the model it is further assumed that the technology does not change when a farm concludes a plant species protection contract. Feed production can differ between different types of land and is dependent on the level nitrogen applied (see Appendix 1 for a detailed description. There are no non-negativity constraints for bought feed and nitrogen surplus because farms can decide to sell feed produced and use nitrogen from other farms. It is assumed that farms use the maximum amount of 250 kg N from animal manure per hectare., N fertiliser use is less or equal than 148 kg N/ha. These amounts follow from Dutch manure policies.

4.2 Data

A survey was used to get information about the relevant variables. The used sampling strategy was a random sampling among all the farms in the Acherhoek a region in the eastern part of the Netherlands (four municipalities: Aalten, Berkelland, Groenlo en Winterswijk). The population density is about 293 inhabitants/km^2 and the area is about 604 km^2. It is a small scale landscape with tree rows aside the roads; it has forests, several brooks (north and south, streaming from east to north- and southwest), and many pastures. The main farm activity is dairy farming (on average about two-thirds of the farms). Nitrogen and phosphate concentrations in groundwater are rather high in this area.

The sample consists of 1380 farms. A questionnaire was developed and pre-tested by experts in the field of farming and agri-environmental schemes and by individual farmers. After pre-testing the questionnaire was adapted. After about three weeks, all farmers to whom a questionnaire was sent received a reminder letter. In total 333 of 1380 farmers sent back the filled-in questionnaire; a response rate of almost 25 per cent. This percentage is reasonable given the methodology of the questionnaire.

First a set of questions were asked to clarify the farm type (crop and animal activities) and location of the farm. A second set of questions ask about the farm's labour input. A third group of questions concerns production issues, grazing and grassland types. Fourth, questions are asked about the (land) ownership structure of the farm. Fifth, questions are asked about multifunctional farming activities including wildlife and landscape management. Finally, a number of questions are asked about the age structure of the farm household, their education level, time allocation, continuation of the farm (succession) and the farmer's trust in the government.

Table 1 gives an overview of a number of relevant characteristics of farms in the sample. This study concentrates on very specialized dairy farming and mixed dairy pig fattening farms of which 151 farms were in the sample. Farmers ranked their grassland into good, medium and bad quality grassland. This means that we did not measure differences in grassland quality but we asked farmer for subjective judgements. Farmers were asked to base their ranking on the following two criteria: (1) the suitability of grassland for grazing; and (2) the contribution of grassland to roughage production. Most farmers have high productivity land (146 out of 151) and a minority has low productive land (52 out of 151). About 24% of the farmers judged that they only have good or medium quality grassland.

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[2] Net means total nitrogen production corrected for losses via ammonia emissions from stable and storage.

The use of several quality categories by farmers shows in the first place that they do not consider farmland to be homogenous.

Table 1. Sample characteristics specialised dairy farms and mixed dairy pig fattening farms, 2004

		Average	Standard deviation
Number of farms		151	
	Specialised dairy	125	
	Mixed dairy/pig fattening	26	
Farm size (ha)			
	Good grassland	20.2	9.1
	Moderate grassland	4.3	4.6
	Bad grassland	1.2	2.2
	Maize	9.6	5.3
	Plant species protection contracts (mainly on grassland)	1.5	5.3
Milk production (kg)		515945	215010
Number of dairy cows		65	24
Number of pigs		803	927
Price milk (€)		0.32	0.01
Nitrogen production (kg N per farm)		9002	3538
Total feed required (NEL[3])		3972484	262406
Percentage of farmers grazing dairy cattle		15%	
Farms with plant species protection contracts (%)		22%	
Farms with landscape management contracts (%)		17%	
Percentage of farmers that are member of an environmental co-operative		28%	

Source: Farm survey

Farms-size and milk production are comparable to the average farm size in the Netherlands. The average number of cows is about 65 and this is larger than for the Dutch average dairy farm. However, the farms in the set are specialized dairy farms. Total N production per farm is calculated using technical data on the relation between the milk production per cow and nitrogen excretion per cow (see Hoop, 2004). Milk production per cow is derived from the questionnaire. About 27% of all farms conclude wildlife and landscape services contracts. About 28% of the farms is member of an environmental co-operative. These co-operatives are groups of farms co-operating with the aim of preserving wildlife and landscape and combining this activity with farming.

Dry matter yield for grassland management with restrictions will be in the range of about 4 to 12 to ton/ha/year depending on manure application and the delay of the first cut of grass (following Dijkstra, 1991 and Geerts and Korevaar, 2004). In addition, a lower digestibility (caused by an agri-environmental scheme) causes a lower intake of grass and roughage. This means, in combination with the lower energy value (less manure), a smaller energy intake, which lead to lower animal production and/or the needs for extra supplementary feeding with for instance concentrates (Korevaar, 1986). Berentsen en Giesen (1995: 160) argue that energy production mainly depends on soil type, on the ground water table and the level of N use. These factors were addressed in the questionnaire. The judgements of farmers were analysed by asking to farmers to what extend a number of external circumstances relevant for grassland quality apply on the distinction between good, medium and bad quality. Table 2 shows the characterisation of good, medium and bad quality grassland.

[3] The energy requirement is defined as the required Net Energy for Lactation (NEL; see Ven (1992: 24-25) for the definition of NEL)

Table 2. Grassland quality differences (number of observations is 151), 2004

Grassland quality	Number farms	Share of land (percentage)				
		Production level (ton dry matter per ha)		Sandy soils	Ground water level is satisfactory	Drainage of water is satisfactory
		More than 10	Between 5 and 10			
Good	146	85	15	93	90	90
Medium	106	26	70	74	44	36
Bad	52	6	60	59	36	25

Source: Farm survey

The answers on productivity levels for good, medium and bad quality grassland correspond to the question to rank their grassland. Sandy soils are considered to be better soils for grassland compared to other soil types present in this region. The judgement of grassland quality is in line with the soil quality. The ground water level and water drainage are satisfactory for most good grassland and less satisfactory for medium and bad quality grassland. The subjective estimates of farmers on dry matter yields are used as maximum dry matter production of grassland in the model.

Farms have two options to react on the restrictions due to the measures in the agri-environmental contract: producing less milk and buying concentrates in order to compensate for the loss of the feed content of roughage. The first option is not very realistic in the Netherlands given the high profitability of producing milk. The loss of feed content and the concentrates to be bought are both measured in NEL.

The actual application per hectare of fertilisers is asked in the questionnaire for good, medium and bad quality grassland. Manure application on grassland is also asked. For manure we use a working coefficient (z) that indicates that 1/z kg N in manure is necessary to replace 1 kg N in fertiliser for the same yield (following Buysse et al., 2005). Working coefficients are taken from de Hoop et al. (2004: 21) and only dependent on manure type. For fertilisers the working coefficient is 100%. For grazing dairy cattle the working coefficient in 2009 is set at 45%. If the dairy cows that are not grazing and fatting pigs the norm for manure is 60%. Figure 1 shows the calculation of nitrogen surpluses on farm level.

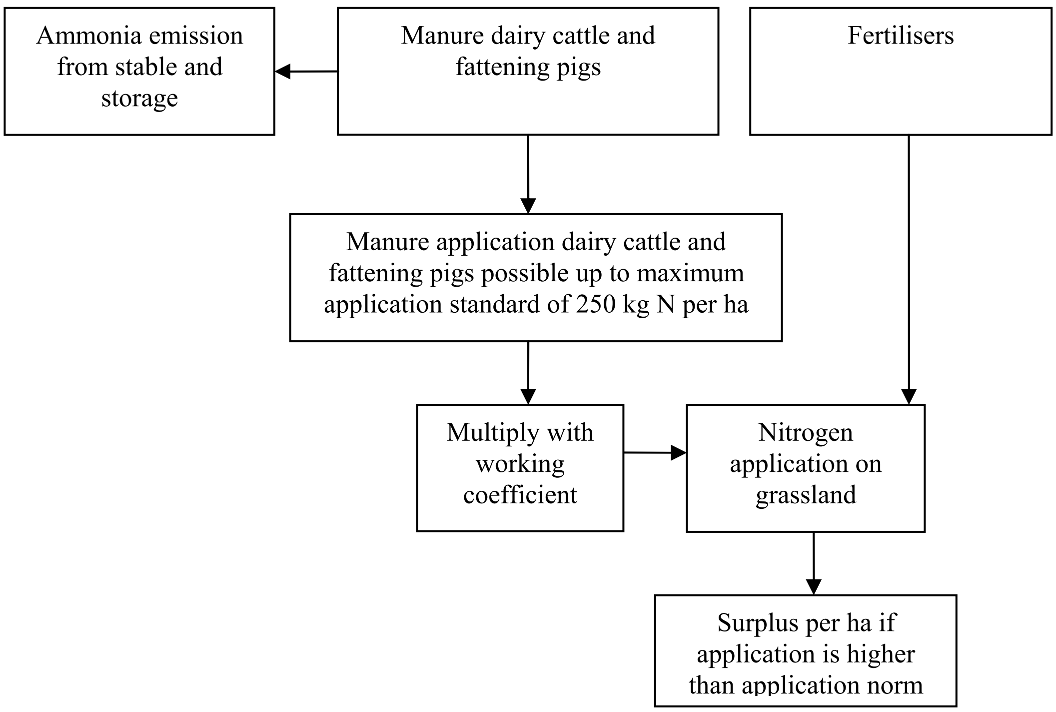

Figure 1. Calculation of nitrogen surplus on mixed dairy/fattening pig farms

The application of manure is restricted by a maximum of 250 kg N per ha. Establishing a limit on N supply in animal manures while ignoring mineral N-inputs is not justified, as one substitutes the other and not only with respect to crop nutrition, but also to N-losses to the environment (Berge et al., 2002: 237). The stable and storage ammonia emission are dependent on the type stable and whether cows are grazing or non-grazing. The maximum application of nitrogen from both manure and fertilisers is restricted by of the new Dutch manure policy starting in 2006. The maximum allowed application is dependent on soil type and crop type.

The application of manure and fertilisers give the total N-application of farm level. Higher grassland production implies the application of more N/ha on grassland. This has also consequences for the nitrogen balance on farm level. Moreover, different application standards apply for land used for plants species protection contracts and land not used for plant species protection (Geerts and Korevaar, 2004). In the simulations we will assume no N can be applied. For maize only one nutrient rate is used because production response to nutrients is low (e.g. Berentsen et al., 2000: 128).

5 Simulations and results

5.1 Scenarios

Using the model and data described in Section 4 we now determine the optimal contract choice for the 151 selected farms under different scenarios. In the base scenario (S0) the data apply as described in Section 4.2. A contract is concluded for a period of 5 years. It is assumed that farms are confronted with both fixed and variable transaction costs. It is assumed that fixed transaction costs only apply for the first year the contract is concluded (€175). The discount rate is assumed to be 5%. Moreover, variable transaction costs are assumed to be 22.5% of the compensation paid to farms. The price of bought feed (concentrates and roughage) and the compensation per hectare contracted are assumed equal between farms and value 0.034 €/kg NEL and 975 €/ha respectively. To examine the effect of transaction costs, changing manure policies and lock-in on contract choice we define four additional scenarios.

S1: Transaction costs
S1 analyses the effects of an increase of variable transaction costs e.g. because of more strict requirements in the plant species protection contract. The variable transaction costs are increased from 22.5 to 45%[4]. This decreases the compensation for contracted land. It is to be expected that a decrease in compensation lowers the number of hectares of land contracted. This effect could be partially offset by a decrease in N disposal costs and a decrease in feed costs.

S2: Manure policies
We calculate here the effects of a change in manure policies. Instead of an application standard of 250 kg N from animal manure per hectare for regularly used grassland, 150 kg N from animal manure per hectare of fodder maize and 0 kg N per hectare of land contracted we assume the application standard for grassland becomes 170 kg N per hectare from animal manure. The 250 kg N per hectare is the present norm for 2009, 170 kg N per hectare is the norm if the Dutch derogation request for 250 kg N per hectare would be rejected. The total amount of N from fertiliser remains 148 kg N or less in both cases. More strict manure policies could decrease the amount of land contracted because less N can be put on contracted land.

S3: Feed prices
We calculate here the effects of a 25% increase in feed prices. Higher feed prices make it more attractive to produce feed on the farm. Given that land contracted produces less feed this makes concluding a plant species protection contract less attractive. Higher feed prices could follow from

[4] Sensitivity analyses show that although fixed transaction costs do influence profit they do not influence contract choice in any of the scenarios defined.

reduced N use, and therefore, smaller feed production coming from more strict manure policies in the Netherlands.

S4: Lock-in

In this scenario we illustrate the possibility of lock-in. Suppose farms conclude a contract for a five year period. After this five year period they are confronted with a 50% reduction in the compensation paid in the plant species protection contract. This makes concluding a new contract less attractive. However, assume that not concluding the contract involves an extra investment because of grassland renewal. We assume here that farms are not aware of the reduction in compensation paid in period 2. Therefore, they do not take the possibility of lock-in into account.

5.2 Results

Table 3. Change in the number of farms concluding plant species protection contracts and the average percentage change of compensation paid per farm, costs of N-surplus disposal, bought feed, area contracted and fertiliser cost.

	S1	S2	S3
Revenue nature (Δ%)	-92	0	-89
Cost N surplus (Δ%)	-60	54	-60
Cost bought feed (Δ%)	-20	+0	-2
Area under contract (Δ%)	-89	0	-89
Cost fertiliser use	0	89	23
Number of farms concluding contracts (Δ*N*)			
• High quality (22)	-22	0	-22
• Medium quality (78)	-74	0	-74
• Low quality (49)	-31	0	-31
• Total (99)	-77	0	-77

Table 4 confirms that under S1 the amount of land contracted decreases if variable transaction costs increase. This decrease implies that more N can be applied on land because of the zero application norm for contracted land. This lowers the costs of N disposal or increases the revenue from applying manure from other farms on-farm. The larger production of feed on land not contracted lowers the amount of feed bought, and therefore, the costs of bought feed. Fertiliser use remains constant. This result is due to the fact that some farms do not use fertiliser on regularly used land. For these farms N from animal manure is sufficient to produce the feed required and extra revenue from selling feed does not outweigh fertiliser costs. A switch from contracted land to regularly used land does not lead to a change in fertiliser use for these farms. In the base run farms using fertiliser use 78 kg N per hectare. In total 77 farms stop concluding plant species protection contracts.

In S2 more strict manure policies do not lead to less farms contracting land. The more strict application norms increase the N surplus, and therefore, N disposal cost. The decrease in N from manure availability makes it attractive to buy extra fertiliser to maintain feed production at the same level. Farms using fertiliser start using the maximum amount of 148 kg N per hectare. Given that the same amount of land is contracted the demand for bought feed remains equal. However the small decrease in total N use lowers feed production slightly, and therefore, leads to a small increase (0.3%) in feed bought.

Higher feed prices in S3 make it more attractive to produce feed on-farm. This leads to less land contracted. In total 77 farms stop concluding plant species protection contracts. Because less land is contracted more N can be applied on-farm because of the higher application standards for regularly used land. This decreases N disposal costs or increases revenue from applying manure from other farms on-farm. The decrease in land contracted leads to a decrease in the amount of feed bought. Fertiliser use goes up because it is more attractive to produce feed on farm.

In S4 we look at the possibility of lock-in. Initially 99 farms conclude plant species protection contracts. Suppose now that farms expect the compensation paid to remain unchanged. This implies that a price fall comes unexpected. If the compensation falls with 50% of the initial 99 farms 22 farms would still conclude a contract. Only 8 farms would contract the same amount of land. 77 farms would like to stop the contract. However, taking into account the switch costs in year 6 (the beginning of the second period of five years) of more than 1150 euro per hectare would imply that all farms that initially had a plant species protection contract will renew the contract although they would have not done this without the switch costs. So all farms are locked in when switch costs are higher than 1150 euro per hectare.

6 Summary and conclusions

This paper presents a theoretical and empirical model that can be used to model plant species protection contract choice on farm level. The model assumes contract choice is strongly determined by the differences in N application and feed production between regularly and contracted land. The paper analyses the role of transaction costs and change in manure policies on contract choice and the possibility of lock-in situations. The model is applied on 151 farms taken from a sample drawn from a farm survey held in the Achterhoek a region in the Netherlands.

Results show that higher transaction costs, more strict N application standards and higher feed prices lead to less land contracted. However, higher transaction costs and feed prices and manure policies do not automatically lead to less land contracted. For some farms this is the case but not for all. Moreover, the level of changes is relevant. This illustrates the importance of farm-specific models. Also the possibility of lock-in is illustrated. Given that the quality of land falls if plant species protection contracts are concluded extra costs have to be made to recover land quality (e.g. grassland renewal). This forces farms to renew contracts although the terms (e.g. compensation paid) of a contract are worsened.

The analysis is subject to some qualifications. First, we use a linear programming model. So, there is no continuous adjustment but the outcomes 'jump' from one equilibrium to another. Given that we build models for a large number of farms makes the jumps for the average farm smaller but they are still present. The fact that we have a model with a small number of restrictions makes the reactions also less continuous. Second, the model does not calculate back the actual amount of land contracted. The reason for this could be that in reality there are different types of contracts that farms can conclude. Using PMP (Positive Mathematical Programming) the model could be 'forced' to calculate the actual amount of hectares contracted. In reality 39 out of the 151 farms conclude a plant species protection contract, in the model 99 out of 151 farms conclude a contract.

Despite the qualifications the approach discussed is flexible because it makes it possible to introduce all kinds of technical and institutional restrictions (e.g. contract time), transaction costs and policies. Given farm-specific/contract-specific outcomes, the survey and model can help to better understand reasons why farms conclude a specific contract and what the consequences are for production, profit, etc. This information is relevant given the larger emphasis the EU is putting on quantifying the effects of agri-environmental policies.

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Appendix 1:

The yield of grass is expressed in tons dry matter (DM) cut^{-1}. The energy value of forages is expressed as net energy for lactation (NEL, kJ kg^{-1} DM). Multiplying the DM yield ha^{-1} of each cut by the corresponding energy value per kg dry matter and adding up for all the cuts results in the annual energy yields. The use of N fertilizer is important in intensive grass-based dairy farming, as it affects dry matter yield and crude protein concentration in the herbage (Vellinga et al., 2004: 365). Grass can be produced at different rates of nitrogen from fertilizer and manure application (kg N ha^{-1} $year^{-1}$). Several studies show the effects of N fertilization on forage production in dairy farming systems (e.g. Middelkoop and Aarts (1992); Ven (1992); Valk et al. (2000); Berge et al. (2002); Nevens and Rehuel (2003); Trott et al. (2004); Vellinga et al. (2004). For this paper, the relation between N-application and NEL production per hectare per year is adapted from Ven (1992), Groeneveld et al. (1998), Groeneveld et al. (2001) and Nevens and Rehuel (2003)). Further, we assume that all farms apply grazing on their farm. Grazing is less efficient than mowing with equal amount of N-fertilization.

The total supply of nitrogen (N) per year for grassland is calculated as follows:

supply = manure + fertiliser + deposition + mineralisation

With:	supply	=	supply (N)
	manure	=	250 kg N/ha from animal manure
	fertiliser	=	endogenous but less than 148 kg N/ha, can be different for good, medium and bad quality of grassland
	deposition	=	assumption: 50 kg N/ha
	mineralization	=	assumption: 250 kg N/ ha

For land contracted both N from manure and fertiliser are zero.
Not all supplied nitrogen will be available for grass because of nitrogen leaching. From supply and leaching the available nitrogen can be derived (Bouman and Hermans, 1997):

leaching = 15 + 0.32(supply-300)
na = supply - leaching

With	leaching	=	leaching N/ha
	na	=	available N/ha

Only part of the nitrogen from the available nitrogen is taken up by the sward (see also Middelink and Aarts, 1991: 35-36; van der Ven, 1993: 23-26):

$$nu = \frac{(-(\alpha_b + na) + ((\alpha_b + na)^2 - 4\alpha_a\alpha_c na)^{0.5})}{-2\alpha_a}$$

With	nu	=	uptake N/ha
	α_a	=	constant (1.14)
	α_b	=	ratio α_b / α_c (= 1.176 × α_c)
	α_c	=	horizontal asymptote that is 11.85% above maximum nitrogen uptake (=43.6×(1+0.1185)×maximum dry matter production)

The maximum dry matter production is derived from the questionnaire and is based on subjective judgments of individual farmers. The actual dry matter production depends on the nitrogen uptake of grass (Middelink and Aarts, 1991:27-29 and Groeneveld et al., 1998: 29):

$$dm = \frac{(-(\beta_b + nu) + ((\beta_b + nu)^2 - 4\beta_a \beta_c nu)^{0.5})}{-2\beta_a}$$

With	dm	=	dry matter yield per ha
	β_a	=	constant (19.88)
	β_b	=	$21.6 \times \beta_c$
	β_c	=	$1.078 \times$ maximum dry matter production

The energy production (NEL) per kg dry matter is based on grazing (adapted from Groeneveld et al., 1998: 35, Middelkoop and Aarts, 1991; and Ven, 1993 and Nevens and Rehuel, 2003):

$$NEL = \gamma_0 + \gamma_1 nu + \gamma_2 nu^2$$

With	NEL	=	net energy for lactation (kJ per kg dry matter)
	γ_0	=	5947.932
	γ_1	=	15.0628
	γ_2	=	-0.020439

The total dry matter production per ha per year (fz_r^i and fz_n^i) is calculated by multiplying the NEL per kg dry matter with the total dry matter production per ha (so: dm $\times$NEL). Note that dry matter production per ha differs between good, medium and low quality grassland.