Effectiveness of markets in nitrogen abatement: A Danish case study

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Abstract

Degradation of water ecosystem caused by excessive loads of nutrient from agricultural sources continues to be a problem in many countries. Targeted regulation has been suggested for implementation of nitrogen (N) abatement measures to achieve N reductions. Achieving cost-efficient implementation of N abatement actions may depend on farmers' response to the suggested policy. In this paper we present a method for analysing farmers' likelihood of engaging in N abatement trading contracts. By use of a hypothetical market experiment we derive the demand and supply functions for Danish farmers. Our findings suggests, that farm and farmer characteristics influence, not only the decision whether to participate or not and whether to supply or sell N abatement, but also on the amounts to be traded. We conclude that introducing trade as an N abatement policy measure involves challenges due to the spatial specificity of the abatement targets leading to small markets and lack of heterogeneity. The results can be used to support the design of policy incentives used to address nutrient reductions.

Keywords

Nitrogen abatement, agriculture, cap and trade, farmers, choice modelling, market functions

1 Introduction

Excessive loads of nitrogen (N) and phosphorus can cause eutrophication and alter freshwater and marine ecosystem dynamics (Coppens et al. 2016; Maar et al. 2016; Brookes and Carey 2011), resulting in altered regulation of food webs and water quality as a result of algae blooms (Riemann et al. 2015; Conley et al. 2007; 2009). Eutrophication, oxygen deficit and hypoxia can result in negative impacts on ecosystem services from marine and freshwater ecosystems such as fisheries (Breitburg 2002; Claireaux and Dutil 1992; Baden et al. 1990) as well as recreational opportunities (Kosenius 2010; Eggert and Olsson 2009; Kaoru 1995). In most parts of the Western world the origin of nutrient loads is predominantly from agricultural systems (Sutton et al. 2011; Vitousek et al. 2009), although emissions from households and industry also contribute to the nutrient balance (Sutton et al. 2011). In Europe, the policy need in this area has been recognised for many years and led in 2000 to the European Water Framework Directive (WFD) with a binding target of achieving good ecological status in all natural surface and ground waters (European Parliament, 2000). The national implementation of the Directive has generated a research need to identify suitable policy instruments including analyses of pros and cons of alternative policy options.

For implementation of the WFD, spatially differentiated regulation by targeting abatement actions has been motivated from both environmental (Refsgaard et al. 2014) and economic rationales, where the economic rationales have been considered using, among others, cost minimization models (Savage and Ribaudo 2016; Hasler et al. 2014; Konrad et al. 2014; Wulff et al. 2014; Kuwayama and Brozović 2013; Johansson and Randall 2003; Fröschl et al. 2008; Schou et al. 2006), econometric modelling (Fezzi and Bateman 2011, Hutchins et al. 2009), and policy scenario analysis coupled to farm economy and nutrient emission models (Caille et al. 2012; Bartolini et al. 2007; Lacroix et al. 2005).

Targeted regulation can be based upon different parameters. Kuwayama and Brozović (2013) conclude that a spatially differentiated groundwater pumping permit system reduces total and marginal abatement costs compared to a uniform system which do not account for spatial heterogeneity. Spatial heterogeneity refers to differences in effect on stream flows from pumping far away or close to the stream. Savage and Ribaudo (2016) illustrates that the efficiency of technology-based measures can be improved by targeting measures to cropland with low marginal abatement costs. Konrad et al. (2014) and Hasler et al. (2014) conclude that efficient load reductions of nitrogen from agricultural catchments are highly dependent on targeting according to abatement cost and the sensitivity of catchment basins and water retention capacity. Wulff et al. (2014) and Schou et al. (2006) also consider targeting due to differentiated abatement targets in specific sea regions taking cost functions and N retention estimates into account. Johansson and Randall (2003) combine the spatial phosphorus index and farm productivity, to analyse on targeted phosphorus abatement policies.

The coastal catchment basins and the agricultural catchment areas are interlinked through a specific network of waterways. Therefore, N abatement in one catchment cannot substitute N abatement required in a different catchment, i.e. targeting abatement to the specific agricultural catchment is necessary to obtain the required water quality at the coast. Farm economic arguments have been highlighted in support for targeting of abatement effort as a way of achieving cost efficient implementation, and hereby reduce the costs for the farmers (Savage and Ribaudo 2016; Hasler et al. 2014; Konrad et al. 2014; Kuwayama and Brozović 2013). Therefore, heterogeneity of farm and farmer characteristics can play a role in targeted regulation efforts, as cost of implementing abatement measures will vary across farm types and agricultural land.

Targeted regulation has mainly been analysed in the above mentioned cost minimization models analysing the optimal way of reaching nutrient reduction targets, by identifying efficient combinations of nitrogen abatement measures within a catchment area). The models take the spatial heterogeneity in land productivity, abatement costs, recipient sensitivity and/or N retention capacity into account. These are important features in the targeted regulation debate, as the catchment basins can vary substantively in environmental sensitivity and N retention can vary not only between but also within catchment areas (Refsgaard et al. 2014). However, the solutions obtained by the cost-minimisation modelling might not reflect well individual farmer's likely response to increased efforts in N regulation. Econometric models and scenario analysis may be more suitable tools for analysing farmer response to different policy incentives (Fezzi and Bateman 2011), but require time series data.

Another part of the literature analyse on the design of optimal contracts proposed to the farmers for implementation of different abatement measures or management methods to reduce the emission of nutrients (Giovanopoulou et al. 2011; Page and Bellotti 2015). Information on how farm and farmer characteristics influence farmer preferences for alternative voluntary nitrogen abatement contracts is important for the assessment of the likelihood of signing up to targeted abatement policies. A design of voluntary contracts with farmers to allow some farmers to exceed their N allowance and others to implement more N abatement than the average catchment requirement could create an incentive to trade N abatement requirements across a catchment and potentially reallocate N abatement and achieve a more costs-effective implementation.

The literature on water quality trading is substantial, especially studies on trading between point source dischargers and non-point sources (O'Grady 2011; Lankoski et al. 2008; Breetz et al. 2005; Fang et al. 2005; Horan et al. 2004). Studies in water quality trading between non-point dischargers, such as agricultural farms, are emerging, and have been considered in studies applied in different agricultural systems (Rabotyagov et al. 2013; Prabodanie et al.

2014; Shortle 2012; Kling 2011; Prabodanie et al. 2010). The possibility of trading N allowances between agricultural sources has been implemented in the Lake Taupo program in New Zealands (Shortle 2012; Duhon et al. 2015). In this programme, farmers are allocated individual N allowances based on historical discharges. Farmers who seek to increase their N discharges above their allocated level have the possibility to buy allowances from others (Shortle 2012). Farmers are also allowed to sell allowances to a public fund (Duhon et al. 2015).

Rabotyagov et al. (2013) suggest a system where farmers are allocated on-farm N reduction targets based on an estimated least cost allocation of abatement measures. Each farmer has to meet the target, but is allowed to choose another combination of measures as long as he fulfils the same edge-of-field emission reduction as estimated with the model. Rabotyagov et al. (2013) suggest trading of effect obtained from implemented abatement measures between farmers to improve efficiency. Kling (2011) suggest assigning each conservation practice per land parcel a point value based on the effectiveness at reducing emissions at the field. The point values could be chosen based on expert statements and informed by biophysical models. The farmers' incentive to implement or trade in conservation practices is given by a cap on points per watershed. Hung and Shaw (2005) suggest a trading-ratio system for water pollution control based on zonal specified caps due to upstream-downstream spatial locations. Prabodanie et al. (2010; 2014) applies an LP model to elicit analytical solutions to efficient tradable N pollution permits for a future market, taking catchment hydrogeology into consideration. They define permits as allowable nitrate loading to a groundwater aquifer and illustrate how the market price structures changes to satisfy different environmental conditions.

However, even though a trading system could be beneficial to the involved farmers, incentive to participate in the market might be influenced by the spatial configuration of N abatement obligations, the design of the trading system and the allocation of farm types and farmer characteristics. The purpose of this paper is to investigate how farmers might respond to an introduction of a voluntary N trading system. We approach this question by studying farmers' choices in a hypothetical market experiment, where the individual farmer has the choice between meeting his or her own abatement cap, and trading allowances with other farmers. Given the price on N, farmers can choose if and how much additional abatement they would offer to deliver on their land. Similarly, how much of their own abatement cap they would pay others to deliver. The data is collected from a national scale survey of Danish farmers conducted during winter and spring 2016.

As a voluntary mechanism the efficiency gains are only achieved if farmers have an incentive to trade abatement effort. The efficiency of such a market is likely not only to depend on how the market mechanism is designed but also on the distribution of farm and farmer characteristics. Farmers' behaviour is likely to depend on a range of spatially specific biophysical conditions, and farm and economic parameters determining the effectiveness of abatement technologies and farm productivity (Vaslenbrouck et al. 2002; Page and Bellotti 2015; Greiner 2015) as well as trust and communication can influence on farmers participation in water quality trading (Breetz et al. 2005). We test whether and how farmers trading behaviour is influenced by these biophysical and economic factors. We also investigate whether and how the size of the introduced N cap influences farmer decision-making. We investigate this by using a latent class choice model (LCM), and analyse the different resulting segments in terms of farmer and farm characteristics. We also investigate whether and how the size of the introduced N cap influence on farmer choices.

As mentioned earlier, abatement actions should not be transferred between catchments, i.e. trade are not allowed between catchments but carried out in smaller markets defined by farmers within a specific catchment area. From the data we are not able to investigate farmers within specific catchments. However, by using national data, we are able to investigate the influence of the difference between the introduced N caps and farm and farmer heterogeneity on trading behaviour. We find that farm characteristics influence both the choice of delivering or purchasing N in the market as well as on the amounts they are willing to trade.

The paper is organised as follows. Section 2 describes data and the method used in the analysis. We describe the choice experiment design and illustrate the choice cards. Furthermore we describe how the supply and demand abatement functions are specified. Section 3 shows the results. We provide a descriptive analysis of data showing the heterogeneity of farmers affect their decision making regarding being preferable suppliers or demanders of N to the market. We present the results from the CE analysis and the demand and supply abatement functions. In section 4 we discuss the reason for farmers to choose opt-out, the influence on farmer choices from heterogeneity in N-cap, and which obstacles our findings suggests for trade in smaller markets. Finally, in section 5, we present our conclusions.

2 Data and methods

We employ a choice experiment (CE) methodology to investigate how farmers are likely to respond to implementation of a cap and trade policy on N abatement. The data for the analyses gives key characteristics of the farm (farmer) including their trade-choices made given an abatement requirement specific to each of the catchments included in the survey. For a given choice situation, the hypothetical market gives the price for trading N abatement, and given this price level farmers can then choose whether or not to participate, the extent of participation and, if decided to supply N to the market, how to implement N abatement on their farm. In the following we first outline the data collection process generating the national survey data. Secondly, we specify the CE design in more detail and give an overview of the data used for the analysis in this paper. Thirdly, we outline the procedure for estimation of supply and demand curves for N abatement.

2.1 Data collection

We design a national scale survey to capture both the spatial variation in catchment specific N abatement requirement and the heterogeneity of farm and farmers characteristics across the country. The catchment specific total N abatement target, $N_{Catchment}^{Target}$, used for setting up the cap and trade system is determined with reference to the difference between the current ecological status and the good ecological status as specified by the Danish Nature Agency (Ministry of Environment and Food 2014). The total N abatement is then distributed to the farmers (Eq. 1) using the average catchment N retention, $Retention_{Catchment}$, and the size of the total cultivated area in the catchment, $Area_{Catchment}$. The N abatement requirement on the farm, N_n^{Req}, depends then on both the N abatement target in the water body and the average N-retention between the field and the down steam water body.

$$N_n^{Req} = N_{Catchment}^{Target}/(1 - Retention_{Catchment})/\ Area_{Catchment} \qquad \text{(Eq. 1)}$$

In this way, farmers within the same catchment have the same N abatement requirement in kg N per hectare, but the requirements vary between catchments due to the sensitivity of the water body. The spatial variation in N-retention implies that a larger share of excess fertiliser application in low retention catchments will end up in downstream freshwater and marine systems compared to high retention catchments. However, it also implies that farms in catchments with a low N-retention, will achieve N abatement downstream with less effort than farms in catchments with a high N-retention. We capture the spatial variation in N-retention[1] using the national GIS layers provided in Højbjerg et al. (2015).

With the specific N-requirement in mind, farmers are asked to choose between different contracts of purchasing or supplying N abatement to the market. It is hypothesised that structural parameters such as farm type including animal husbandry, farm size and soil types, and farming system characteristics such as land cover (having catch crops, energy crops, forests), and preferences due to characteristics of different N mitigation measures will be important for farmers trading behaviour. The variables collected are specified in table 4 in section 2.3 including the variables collected as part of the CE.

The questionnaire was tested in two focus groups and in two interviews, one face-to-face and one telephone interview. After an on-line pilot test the questionnaire was distributed to

[1] The retention GIS layers are estimated as the root zone loses deducted N lost to the downstream water body and withdrawn the effect from N abatement measures (Højbjerg et al 2015). In this way, we do not double count for the N effect from implemented N abatement measures when estimating the obtained N reduction in the downstream water body.

around 10,000 Danish farmers by email in February 2016. The survey was distributed to all farmers in the agricultural register with two follow-up emails. By responding the farmers participated in a random draw of 5 respondents who would receive a gift voucher with a value of 2000 DKK (269 €). Based on the provided answers, farmers are divided into two groups: farmers who could be interested in supplying N abatement to a market and farmers who could be interested in purchasing N abatement from the market. The response rate was 13 % resulting in an effective sample of 923 respondents, of which 470 respondents represented potential buyers and 453 respondents represented potential suppliers of N-effect.

2.2 CE design, attributes and choice cards

Both the demand and supply CE is designed with five different choice scenarios for each respondent, where each scenario represents a market situation defined by a specific price of trading N abatement.

A D-efficient design was chosen as recommended by Bliemer and Rose (2011) (also see Hensher et al. 2005 and Sandor and Wedel 2001) and used in several previous papers. The design was implemented in NGene (ChoiceMetrics 2014). This resulted in a design with six blocks, each containing five choice sets (one for each price level). Each choice set consisted of three alternatives involving trade plus an option not to trade. The no-trade option means that farmers decide to (only) implement own N abatement requirement. Both designs are level-balanced and the price sequence is changed between blocks, so that the five price levels come in varying order in the blocks.

From the question “Would you consider supplying N abatement to a market or purchasing N abatement”, respondents are divided into two sets of data, a demand data set and a supply data set. Each of the two groups is presented with a CE. The attributes included in the CEs (table 1) are chosen to be able to estimate the relation between price and nitrogen.

Table 1: Attributes and levels in the demand- and supply CE

	Demand CE	Supply CE
Attribute	Level	Level
Price, DKK per kg N	5, 12, 30, 45, 80	5, 12, 30, 45, 80
Nitrogen amount in percentage of total N requirement	1, 5, 9, 15, 18, 25, 33, 45, 75, 100	
Contract length (years), combined with a specific N measure giving a specific N-effect		**Catch crops**: *1 year*, 35 kg N/ha if application of animal manure and 22 kg N/ha if no application of animal manure **Energy crops**: *10 years*, 34 kg N/ha if clay soils and 51 kg N/ha if sandy soils **Permanent set aside**: *Permanent contract*, 50 kg N/ha

Area in percentage of cultivated Area (%)		1, 4, 10, 25, 40

Farmers supplying N abatement, choose between different contracts combining contract lengths (implementation of three different nitrogen abatement measures which are characterised by different time horizons), different extents of implementation (percentages of their cultivated agricultural area) and varying market prices (price of nitrogen abatement sold in DKK/kg N). Farmers purchasing N abatement are to choose between contracts with differing amounts of N bought (percentage of their individual abatement requirement) at different market prices (nitrogen abatement bought in DKK/kg N).

Because the CEs are simulating a market situation, for which the market price is given, the respondents can only choose whether to enter the market at the given price level or not. All respondents are presented with all price levels (Table 1), one choice card for each price level (examples of choice cards are given in figure 1 and 2). The price levels are the same for both CE-designs and based on estimates of opportunity costs, implementation costs and N abatement effects. These estimates were compared to Danish cost effectiveness studies of implementation of different N mitigation measures (Hasler et al. 2015, Jacobsen 2012). The price attribute was tested as part of the focus group discussion and in the on-line pilot test. For comparison, the average cost of implementing catch crops, energy crops and permanent set aside, which are the chosen measures used in the supply-CE, ranges from 5 DKK/kg N to 68 kg N/ha (0.68-9 €/kg N) depending on soil type, crop rotation pattern and use of manure (own estimations).

If respondents choose to pay for N abatement, they trade-off their own N abatement options with the price for buying N effect at the market. There are only two attributes. The amount of N the respondents are willing to buy and the given market price. The design therefore resembles a Contingent Valuation payment card approach (Mitchell and Carson 1989) including four levels of nitrogen abatement. But there are also differences as the respondents are presented with all price levels separately. The N-attribute has 10 levels (Table 1). The levels are chosen so that the values span the entire possible interval, i.e. from 0 to 100 percent. With reference to Ryan and Wordsworth (2000) the levels are unequally spaced, with increasing distance between the intervals as the values increases.

If respondents choose to supply N abatement to the market, they are to choose between different contracts defined by contract length and percentage of area to enrol given the market price. The attribute on contract length, is a combination of choice of measure and the corresponding N-effect from implementing this measure AND the duration of that measure. The three measures chosen are catch crops, energy crops and permanent set aside. These are chosen because they represent measures which are relevant for all farmers i.e. they do not dependent on use of manure or hydrological characteristics of the land.

Furthermore, they differ in implementation costs, duration and effect. Implementation costs are not a direct part of the attribute, but a parameter known by the farmer, but partly hidden from the policy maker. Finally, all three measures are known to farmers in Denmark as they are all part of existing regulation (NaturErhvervstyrelsen 2015). Contract length is an essential attribute because of the high option value of having the possibility in the future to take land into cultivation. Contract length is proven to be important for farmers in earlier surveys (Broch and Vedel 2011, Christensen et al. 2011, Ruto and Garrod 2009). Permanent set aside is the same as partly giving up the property right of the land, i.e. giving away the right to make land use choices on owned land.

The second attribute, area, is a 5 level attribute, and measured as a percentage of arable land allocated for N abatement. The levels are chosen so that the values span the realistic intervals for all three N abatement measures given implementation costs, N effects and market prices on N abatement.

Examples of each of the choice cards[2] are given in Figure 1 and 2.

Choice card 1 of 5. Imagine that the price for buying N-effect is: 5 DKK/kg N per year			
	Contract A	Contract B	Contract C
Amount of N	15 % of your total N requirement – correspond to 300 kg N	33 % of your total N requirement – correspond to 660 kg N	25 % of your total N requirement – correspond to 500 kg N

Please choose the contract that suits you best
◯ Contract A
◯ Contract B
◯ Contract C
◯ I choose none of the contracts, and choose to fulfil my N-requirement on my own land without buying any N-effect at the market

Figure 1: Choice card – demand data.

Choice card 1 of 5. Imagine that the price for selling N-effect is: 5 DKK/kg N per year			
	Contract A	Contract B	Contract C
Contract length	10 year contract on energy crops. Effect on clay soil = approx. 34 kg N/ha per year and effect on sandy soils = approx. 51 kg N/ha per year	1 year contract on catch crops. Effect if use of manure = approx. 35 kg N/ha per year and effect if no use of manure = approx. 22 kg N/ha per year	Permanent contract on permanent set aside. Effect = approx. 50 kg N/ha per year
Area	10 % of your cultivated area – correspond to 10 hectares	40 % of your cultivated area – correspond to 40 hectares	1 % of your cultivated area – correspond to 1 hectare

[2] Examples in Figure 1 and Figure 2 are given for a farmer with 100 hectares of cultivated area and with an N cap of 20 kg N/ha.

Please choose the contract that suits you best	
◯	Contract A
◯	Contract B
◯	Contract C
◯	I choose none of the contracts, and choose to only fulfil my N-requirement on my own land without selling any N-effect at the market

Figure 2: Choice card – supply data.

Data from the two choice models are modelled using Nlogit5 (Greene 2007) and coded as described in Table 2. Variables used in logistic regressions for analysing different farm segments, are also shown in Table 2. Only significant variables are shown, however, a long list of variables was tested. These are variables on e.g. catch crops, energy crops and fallow, farmers' age and their stated preferences for different N abatement measures.

Table 2: Coding of attributes and levels (Nlogit)

Variable	Definition	Coding	Data
ASC	Alternative specific constant	Opt-out alternative. No contract = 1. Contract alternatives = 0	Demand / supply
Price	Given market price for trading N in DKK/kg N (5 levels)	Linear	Demand / supply
Nitrogen	Nitrogen amount bought on the market kg (estimated from the CE N attribute in percentage of the farmers total N requirement)	Linear	Demand
Time (T2, T3)	Contract length (3 levels). T1 = 1 year contracts, T2 = 10 year contracts and T3 = permanent contracts	Effect coded: T1 is basis level. If T1 is chosen: T2=T3=-1 If T2 is chosen: T2=1, T3=0 If T3 is chosen: T2=0, T3=1 If opt-out: T2=T3=0	Supply
Area	Area in hectares allocated to abatement (estimated from the CE Area attribute in percentage of cultivated area allocated to abatement)	Linear	Supply
PN	Interaction effect, Price x Nitrogen	Linear	Demand
PT	Interaction effect, Price x Time	Linear	Supply
PA40	Interaction effect, Price x (Area40)	Price times the Effect coded Area attribute. If Area40 is chosen: Area40=1 If all other levels: Area40=-1 If opt-out: A40=0	Supply
Husbandry	Farm with husbandry	1(yes) – 2 (No)	Supply
Sows and Suckling pigs	Farm with sows and suckling pigs	1-0	Demand / supply
Slaughter pigs	Farm with slaughter pigs	1-0	Demand / supply
Dairy cattle	Farm with dairy cattle	1-0	Supply

Other cattle	Farm with other cattle than dairy cattle	1-0	Supply
Horses	Farm with horses	1-0	Supply
Clay soil	Clay percentage of cultivated area	Percentage	Supply
Artificial drainage	Percentage of cultivated area being artificially drained	Percentage	Supply
N abatement requirement	N abatement requirement, catchment specific	kg N/ha	Demand / supply
Total N abatement requirement	N abatement requirement, times the individual farm area in rotation	kg	Demand / supply
Area in rotation	Farm area in rotation	Hectares	Demand / supply
Farm area	Owned area plus leased area	Hectares	Supply
Organic	Farm being organic	1-0	Demand
Full time farming	Farmer being a full time farmer	1-0	Supply
Self-employed	Farmer being self-employed	1-0	Demand / supply
Catch crops	Farmers having more catch crops than required by Danish law	1-0	Supply
Energy crops	Farm having energy crops as substitute for the Danish requirement for catch crops	1-0	Demand
Forestry	Farm having forestry	1-0	Supply
Attitudes towards rating of N abatement measures			
Low costs	Low establishment costs	1-2-3-4-5, from no importance to major importance	Supply
Revenue from hunting	Improved possibility of revenue from hunting, and living conditions for game	-//-	Demand / supply
Wilderness	Establishment of (more) areas with potential for wilderness	-//-	Supply
Current crop rotation pattern	Possibility of keeping current crop rotation pattern	-//-	Demand / supply
N effect	High N effect from chosen measure	-//-	Demand
Administration costs	Less administration costs as possible	-//-	Demand / supply
Public access	Avoid public access to the areas	-//-	Demand
Flexible crop rotation pattern	Secure a flexible crop rotation pattern	-//-	Demand / supply
Contract length	How long a period the measure require	-//-	Demand / supply
Prior knowledge	My prior knowledge about the measure	-//-	Demand
Other farmers	How much other farmers in the surroundings use the measure	-//-	Supply
Balanced areas	Secure enough area for application of manure from the husbandry production	-//-	Supply

The Nitrogen levels (nitrogen to be bought on the market) are not level coded, as test runs show a positive linear trend. This is also the case for the interaction effect between Price and Nitrogen (PN). The Nitrogen and the interaction effect variables are included as total kg N for the farm (Eq. 2), as using the total amounts give the best model fit. This is an intuitive finding, as this specification captures more of the heterogeneity in the data and reflects better farmers' decision variables.

$$Nitrogen\ (kg\ N\ per\ farm) = Nitrogen\ (\%) * Nrequirement\ (kg\ N\ per\ ha) * cultivated\ area\ (ha) \qquad \text{(Eq. 2)}$$

Contract length (Time) is effect coded because the preliminary estimations indicate non-linear trends. This might be due to the complexity of the attribute which combines both contract length and nitrogen effect as well as implementation costs are part of the attribute but not describe for the farmer. Effect coding is chosen from dummy coding, because model statistics in this survey, are slightly better for the effect coded model. See e.g Hensher et al. 2005, Alkharusi 2012 or Daly et al. 2016 for an overview of dummy and effect coding).

The Area attribute is not level coded as a linear specification fits the data well. However, the interaction effect between Price and Area (PA) is not linear. A non-linearity point around 40% of the arable land implies that respondents display a price-inelastic behaviour for high levels of land allocation. This is modelled by interacting the price variable with the effect coded Area attribute (PA40). The Area attribute and the interaction between Area and Price included as total hectares (Eq. 3) for the individual farms, as this gives a good model fit and reflect the decision variable of the farmer.

$$Area\ (ha\ per\ farm) = Area(\%) * cultivated\ area(ha)/100 \qquad \text{(Eq. 3)}$$

The interaction effect between Price and Time (PT) is included using a linear specification, i.e. for increasing prices the utility of choosing longer contracts (from 1 year, over 10 years to permanent) increases. The interaction effect is important, because the three different measures differs in N-effect and farmers own perceived implementation costs.

2.3 Modelling choice of trade contract

Following the Random Utility theory (McFadden 1974, 1980, Ben-Akiva and Lerman 1985) and the Lancastrian Economic Theory of Value (Lancaster 1966), an individual, n, choose between alternative options, based on the utility, U_{nj}, of each alternative, j. The respondent chooses alternative j if, and only if, $U_{nj} > U_{ni}$, $U_j \neq U_i$, where i represents the other alternatives. The utility of an alternative, U_j, is divided into two components, an unobservable component ε_{nj} and an observable component, $V_{nj} = f(X_{nj})$, where X_{nj} represents the attributes of each alternative. In the context of this research, the choice attributes are the contract length and N-amount. The probability of individual, n, choosing alternative, j, can be expressed as the probability that the utility of choosing alternative j, U_{nj}, is higher than the utility of choosing any other alternative, U_{in}. Specifying a conditional logit model (MNL), gives the probability distribution across alternatives and individuals as given in (Eq. 1):

$$P_{nj} = \frac{\exp(\beta_1 X_{1nj} + \beta_2 X_{2nj} + \ldots + \beta_k X_{knj})}{\sum_{i=1}^{I} \exp(\beta_1 X_{1ni} + \beta_2 X_{2ni} + \ldots + \beta_k X_{kni})} \qquad \text{(Eq. 1)}$$

Where β is the utility coefficient and X_n is the level of attribute 1,..,k for alternative j and all other alternatives, i, for respondent n. In the MNL model it is assumed that all respondents hold the same preferences for the attributes presented, i.e. it assumes no heterogeneity between the respondents. For the analysis of heterogeneity of respondents, a Latent Class Model (LCM) can be used (Boxall and Adamowicz 2002). The error term is now assumed to be distributed independently across segments, s = (1, 2, …, S) and respondents, n. This means, that for each respondent it is possible to estimate the probability of the respondent belonging to a specific segment, $M_{n,s}$, each characterized by segment specific utility parameters . The LCM model allows for heterogeneity between different segments of respondents; within each segment, however, preferences are assumed to be homogenous. For the LCM model, the probability that individual, n, choose alternative j is given conditional on segment S, (Eq. 2):

$$P_{nj} = \sum_{s=1}^{S}(M_{n,s} * P_{nj|s}) = \sum_{s=1}^{S}(M_{n,s} * \frac{\exp(\beta_s X_j)}{\sum_{i=1}^{I} \exp(\beta_s X_i})) \qquad \text{(Eq. 2)}$$

Where β_s is the utility coefficient within each segment. The probability function given in (Eq. 2) for the LCM model, is used for estimation of the demand and supply functions.

2.4 Abatement demand functions

For each of the respondents we calculate the demand functions. Aggregating across all respondents gives the total demand for each price level.

Each alternative on a choice card gives a percentage of the respondent's N abatement requirement, σ_j, the respondent can choose to purchase. The respondents total N abatement requirement can be estimated from the catchment specific abatement requirement, $Req_{Catchment}$, giving the amount of N that should be abated per ha and the respondents cultivated area in hectares, $Area_n$. From this, we can derive the purchase ($N_{Demand,nj}$) for each of the alternatives, j, and each of the respondents, n (Eq. 3):

$$N_{Demand,nj} = \sigma_j * Req_{Catchment} * Area_n \qquad \text{(Eq. 3)}$$

The choice model specifies the probability distribution across alternatives, j, given the market price scenario, c. Nitrogen demand for each market price level, $N_{Demand,c}$, can then be estimated from (Eq. 2) and (Eq. 3) as given in (Eq. 4):

$$N_{Demand,c} = \sum_{n=1}^{N} \sum_{j=1}^{J} P_{nj} * N_{Demand,nj} \qquad \text{(Eq. 4)}$$

The nitrogen amount demanded, $N_{Demand,c}$, is estimated for each price level, c, given for each possible choice card, and summarized across all respondents and alternatives to give the total demand function.

2.5 Abatement supply functions

For each of the respondents we calculate the supply functions, in the same way as the demand functions.

For each of the alternatives, j, we calculate the corresponding nitrogen amount supplied, $N_{Supply,nj}$, for each of the respondents, n, as given in (Eq. 5):

$$N_{Supply,nj} = A_j * Area_n * E_j \qquad \text{(Eq. 5)}$$

A_j is the level of the attribute describing the percentage of the respondent's cultivated area to be enrolled in a contract to supply N abatement to the market. $Area_n$ is the respondents cultivated area in hectares and E_j is the N abatement effect in kg N/ha from implementing the abatement measure given for each possible choice card.

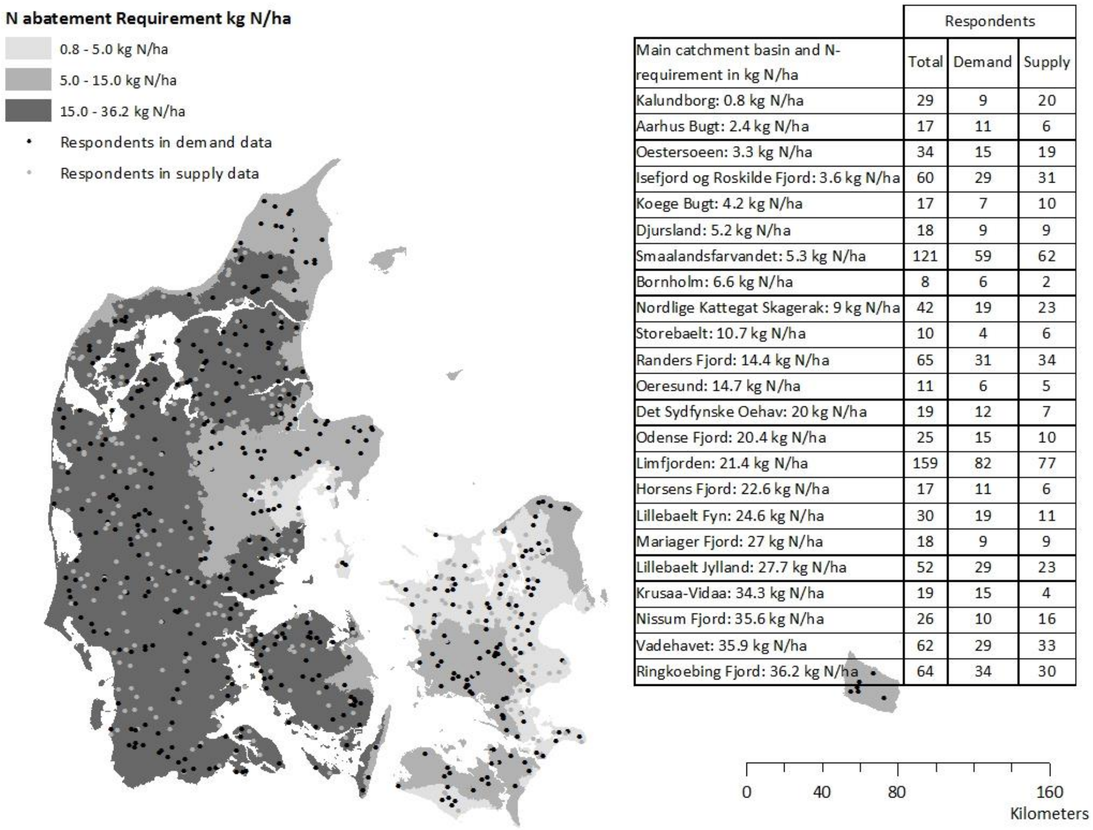
Similarly to the demand estimation, the choice model specifies the probability distribution across alternatives given the market price scenario, c. The nitrogen amount supplied for each market price level given for each possible choice card, $N_{Supply,c}$, can then be estimated from (Eq. 2) and (Eq. 5) as given in (Eq. 6):

$$N_{Supply,c} = \sum_{n=1}^{N} \sum_{j=1}^{J} P_{nj} * N_{Supply,nj} \qquad \text{(Eq. 6)}$$

The nitrogen amount supplied, $N_{Supply,c}$, is estimated for each price level, c, given for each possible choice card and summarized across all respondents and alternatives to give the total supply function.

3 Results

Data consists of 923 respondents in total, 453 in the supply data and 470 in the demand data. Respondents are distributed across 23 main catchment areas in Denmark, each with a specific N requirement given in kg N/ha per year (Figure 3). The N requirements range from 0.8 kg N/ha per year to 36.2 kg N/ha per year. The distribution of respondents between catchments reflects the size of the catchment and is not a weighted distribution.



	Respondents		
Main catchment basin and N-requirement in kg N/ha	Total	Demand	Supply
Kalundborg: 0.8 kg N/ha	29	9	20
Aarhus Bugt: 2.4 kg N/ha	17	11	6
Oestersoeen: 3.3 kg N/ha	34	15	19
Isefjord og Roskilde Fjord: 3.6 kg N/ha	60	29	31
Koege Bugt: 4.2 kg N/ha	17	7	10
Djursland: 5.2 kg N/ha	18	9	9
Smaalandsfarvandet: 5.3 kg N/ha	121	59	62
Bornholm: 6.6 kg N/ha	8	6	2
Nordlige Kattegat Skagerak: 9 kg N/ha	42	19	23
Storebaelt: 10.7 kg N/ha	10	4	6
Randers Fjord: 14.4 kg N/ha	65	31	34
Oeresund: 14.7 kg N/ha	11	6	5
Det Sydfynske Oehav: 20 kg N/ha	19	12	7
Odense Fjord: 20.4 kg N/ha	25	15	10
Limfjorden: 21.4 kg N/ha	159	82	77
Horsens Fjord: 22.6 kg N/ha	17	11	6
Lillebaelt Fyn: 24.6 kg N/ha	30	19	11
Mariager Fjord: 27 kg N/ha	18	9	9
Lillebaelt Jylland: 27.7 kg N/ha	52	29	23
Krusaa-Vidaa: 34.3 kg N/ha	19	15	4
Nissum Fjord: 35.6 kg N/ha	26	10	16
Vadehavet: 35.9 kg N/ha	62	29	33
Ringkoebing Fjord: 36.2 kg N/ha	64	34	30

Figure 3: Respondents distributed on 23 main catchment areas in Denmark

Respondents appear to be evenly distributed across Denmark (Figure 3). Furthermore, a large part of Denmark has high N reduction requirements (dark colour in Figure 3) due to a combination of catchment basin sensitivity, low N retention and the distribution of cultivated areas. More respondents in the catchment areas with high N reduction requirements are seen to be interested in buying N-effect on the market than the respondents in the low-requirement catchment areas, where respondents are seen to be more interested in selling N-effect.

Responses include 2.5 % of all farmers in Denmark and cover approximately 4 % of the total cultivated area. The agricultural area in Denmark is cultivated by a range of smaller farms and a few large farms, with a national average of 63 ha (Statistics Denmark 2015). In the supply data average farm size is 79 ha (median 38) and in the demand data the average farm size is 128 ha (median 76). The distribution on farm size in the supply data is close to the distribution in Denmark, while larger farms are overrepresented in demand data as well as in the national data (average farm size is 104 ha, median 52) compared to the distribution in Denmark. The numbers in Table 3 suggest that, larger farms tend to be more interested in buying N effect, while smaller farms tend to be more interested in selling N effect.

Table 3: Distribution of respondents on farm size (cultivated area)

	<75 ha (%)	75-200 ha (%)	>200 ha (%)

Demand	49	33	17
Supply	71	18	11
National data	60	26	14
Denmark	71.6	18.5	9.9

Furthermore, we find that farmers in the demand data have a larger percentage of their total farm area being cultivated than respondents in the supply data.

Farms with animal husbandry are overrepresented in data with 50 % having animal husbandry compared to 41 % in Denmark (Statistics Denmark 2015). However, the proportion of farms with cattle (milk and beef) is similar to the Danish distribution, whereas pig production is overrepresented in the demand data, as 16 % of the respondents have pigs for slaughtering (10 percent in Denmark) and 9 % rear piglets compared (5 % in Denmark) (Statistics Denmark 2015).

The national data reflects the distribution of fulltime/part-time farmers in Denmark well. However, more part-time farmers are interested in offering N reduction to the market and more full-time farmers are interested in buying N reduction from others. This is in line with the distribution between small and larger farms between the two groups of data, because the larger farms tend to be full- time farmers.

Seven percent of the respondents define their farm type as being organic. In Denmark 8 % of the farmers are organic producers. However, these respondents are not evenly distributed across demand and supply, 71 % of the organic farmers has chosen supply while only 29 % has chosen demand.

3.1 Model specifications and behavioural response functions

For the national data estimations, a latent class model (LCM) specification is chosen. Both the LCM and the mixed logit model (MXL) specification capture the large heterogeneity among respondents and give significant improvement in model fit compared to a multinomial specification (MLN) and as well more significant parameters[3]. In terms of the

[3] Model selection criteria for the MNL, MXL and LCM models:

	LL	Pseudo-R^2	Number of parameters	Adj R2	AIC	BIC
Demand: MNL	-2574.92	0.0133	2	0.0124	2.1939	2.1926
Demand: LCM-3	-2206.58	0.3227	4	0.1530	1.8839	1.8830
Demand : MXL	-2549.15	0.0231	4	0.0215	2.1737	2.1725
Supply: MNL	-2580.58	0.0427	6	0.0401	2.2848	2.2839
Supply: LCM-3	-2074.49	0.2307	13	0.2263	1.8459	1.8488
Supply: MXL	-2561.56	0.0501	6	0.0476	2.2680	2.2671

present analysis, the LCM model specification is deemed superior to the MXL model as the grouping of respondents into different farmer segments based on their stated trading behaviour facilitates the interpretation of results. The choice between LCM models with different number of classes, was based partly on statistical indicators (AIC, BIC and the pseudo R2), but also the distribution of respondents between classes and the interpretation of class specific response functions as representations of behavioural models of different types of farms.

The demand and supply parameter coefficients are estimated using a three segment LCM model (Table 4 and 5) with the utility functions described in (Eq. 5) and (Eq. 6). For a description of the attributes included in the model and coding see Table 2.

$$U_{Demand} = ASC^D + \beta_1^D * Nitrogen + \beta_2^D * PN \quad \text{(Eq.5)}$$

$$U_{Supply} = ASC^S + \beta_1^S * T2 + \beta_2^S * T3 + \beta_3^S * Area + \beta_4^S * PT + \beta_5^S * PA + \beta_6^S * PA40 \quad \text{(Eq.6)}$$

Results from the demand model (Table 4) show three significant segments of roughly the same size, each consisting of 184, 173 and 113 respondents respectively.

Table 4: LCM model results for demand model

Attributes	Segment 1 Estimate	p value	Segment 2 Estimate	p value	Segment 3 Estimate	p value
ASC	-2.60925***	0	.29254**	0.0291	-1.3530***	0
Nitrogen (β_1^D)	0.32887	0.4091	.00021***	0	.00261***	0.0003
PN (β_2^D	-6.57655	0.4092	-.00074***	0	-.02036***	0.0004
Average probability of segment membership						
	.35759***	0.02902	.37135***	0.0335	.27107***	0.03208

***, **, * indicates significance at 1%, 5% and 10% level

Respondents in segment 1 show strong preferences for “Not trading” independent on the attribute levels. 79% (146 respondents) of the respondents in this segment choose opt-out in all 5 choice occasions - this implies that the demand function for this segment essentially is based on the choices made by only 38 respondents. In a follow-up question for those

All demand models are based on a sample size of 2350 and supply models of 2265.
Pseudo-R2 is calculated as 1-LogL/LogL*, where LogL* is the model with constants only being -2696.6 for the supply data and -2696.6 for the demand data.
Adjusted Pseudo-R2 is calculated as R2-(1-R2)*(p/(n-p-1), where p is the number of significant parameters without the constant and n the sample size
AIC is calculated as -2*(logL-K)/n where K is the number of significant parameters including the constant
BIC is calculated as -2*(logL - K*logK)/n

respondents opting out, the respondents could choose between 6 reasons or give another reason in free text format. Sixty percent answered, that they were not interested in trade independent of the market price given. Twelve percent answered that farmers should be compensated for all reductions and a market could therefore not be justified and 12% answered that they do not want to be dependent upon others and therefore choose to solve their N reduction requirement themselves. Only 6% answered that the prices given were too high. A few gave other explanations such as being organic farmers.

Respondents in segment 2 display positive preferences for trading, and an increasing likelihood of participation in the market when the contract offer large N abatement amounts. However, with increasing market prices, the preference for purchasing N abatement decreases. Comparing segment 2 and 3, we find, that the interaction effects between Price and Nitrogen (PN) is smaller for segment 2 than for segment 3, indicating lower price elasticity for this segment than for segment 3.

Respondents in segment 3 show preferences for "Not trading", however not as strong as those in segment 1. No respondents choose opt-out for all choice cards, but in 63% of all alternatives, opt-out was chosen (compared to 96% for segment 1 and 19% for segment 2). In the same way as respondents in segment 2, respondents in segment 3 prefer contracts which offer higher N abatement amounts, and a decreasing likelihood of trading with increasing market prices.

Results from the supply model (Table 5), shows three significant segments, with segment 2 being the smallest corresponding to 81 respondents. Segment 1 and 3 has 221 and 151 respondents respectively.

Table 5: LCM model results for supply model

	Segment 1		Segment 2		Segment 3	
Attributes	Estimate	p value	Estimate	p value	Estimate	p value
ASC	-3.95789***	0	.53200**	0.0159	-.61001***	0.0012
T2	0.16552	0.474	.25174 **	0.0211	-.65437***	0
T3	-.77903**	0.0314	.34589**	0.0159	-.93822***	0
Area	-0.01596	0.3779	-.01931**	0.0289	-.01135***	0.0088
PT	.02080**	0.0181	.00776*	0.0832	.00364	0.571
PA	.03861*	0.0965	-.00798	0.7093	.03836***	0.0001
PA40	-.73252**	0.0335	0.00523	0.9804	-1.12108***	0
Average probability of segment membership						
	.48612***	0	.18960***	0	.32428***	0

***, **, * indicates significance at 1%, 5% and 10% level

Respondents in segment 1 show preferences for "Not trading". Sixty-five present (144 respondents) of the respondents in this segment choose to opt-out in all 5 choice occasions

- implying that the supply function for this segment essentially is based on the choices made by only 77 respondents choose to trade at least in one choice occasion. In the follow-up question for the respondents opting out, the respondents could choose between 5 suggested reasons for opting out and the opportunity to give another reason. Most respondents answered, that they were not interested in trade independent of the market price given (63%). Ten percent answered that they are not interested in implementing any of the suggested N abatement measures and 9% gave other explanations such as being organic farmers.

The likelihood of farmers entering into a contract is low if the contract is permanent (T3), but with increasing prices the probability of entering into a contract with long periods of commitment (PT, where time (T) is linear and increasing) increases. Likewise increasing prices increases the probability that larger areas (PA, where area (A) is linear and increasing) are enrolled. However, the positive effect from increasing prices on Area does not hold for contracts which require an allocation of land higher than 40 % (PA40).

Respondents in segment 2 are inclined to trade and exhibit positive preferences for middle term (T2) and permanent contracts (T3). However, they are not inclined to enrol large areas into the contracts, as the coefficient on Area is negative. With increasing prices they are more likely to select the long contracts, seen from the positive coefficient on the interaction term between price and contract length (PT). This group of respondents include 81 respondents, representing a total of 408 alternatives; of those, 16% were opt-outs.

Respondents in segment 3 appear not to be in favour of trading, however, not as opposed to trading as respondents in segment 1. No respondents choose opt-out for all choice cards, but in 22 % of the choice, the opt-out alternative was chosen. The longer and the more area intensive the contracts, the less likely the respondents are to enrol. With increasing prices we see an increasing probability of entering more area into the contract. However, the respondents are unlikely to enrol very large areas, as evidence by the non-linear effect related to contracts involving areas above 40%.

At least one of the interaction effects between Price and Area and between Price and Time becomes significant for all segments, which show some price elastic behaviour. However, the marginal effects of the interaction term are small compared with the main effects.

3.2 Demand and supply functions

Demand and supply curves are estimated for the national data and for the revealed LCM segments and shown in Figure 5 and Figure 6. These curves are estimated based on the national data, i.e. for all respondents across catchments in Denmark. This is done, to be able to see if a trend exists among respondents due to their farm and farmer characteristics.

Furthermore we investigate whether there is a trend due to the heterogeneity in the N reduction requirement.

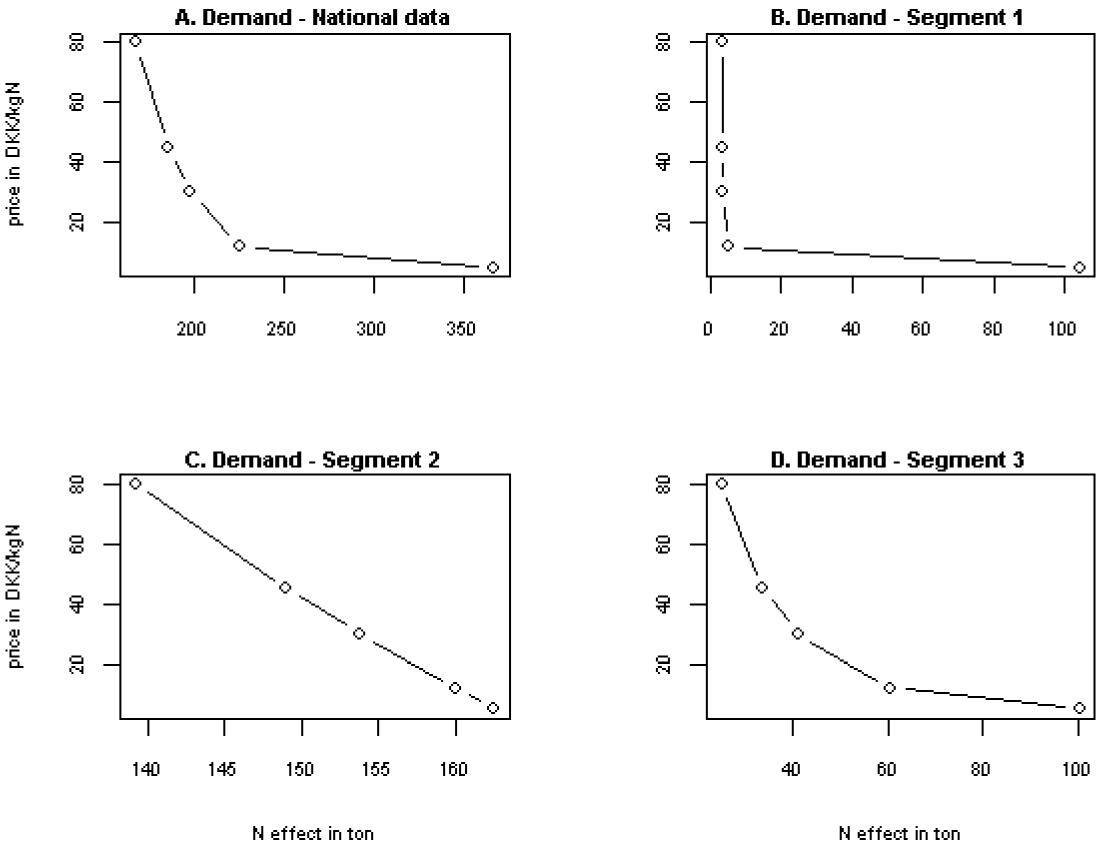


Figure 5: Demand curves for a 3- segment latent class model

Total demand across the national data is shown in figure 5A. Aggregated demand is 367 ton N (in N-effect, N lost to the root zone) if the price were 5 DKK/kg N. Demand covers 470 respondents with a total N-cap of 1,038 ton, i.e. they are willing to buy 36% of their total N-cap if the price were 5 DKK/kg N. This amount is reduced for increasing prices, at a price of 45 DKK/kg the demand decreases to 186 kg N. However, between segments, the demand curves differ substantively. For respondents in segment 1 (figure 5B), encompassing 39% of the respondents, demand is rather inelastic with 79% of the respondents consistently choosing the opt-out alternative. Increasing the price from 5 to 12 DKK/kg N reduces demand to only 5 ton, an amount which remains stable for further price increase. This group of respondents have a strong effect on the aggregated demand. Logistic regression results shows, that the probability of being in segment 1 is larger for organic farmers with low N-requirements. In the demand data in general there are a large percentage of farmers having pig production; however, in segment 1 this percentage is very low.

Respondents in segment 2 (figure 5C), covering 37 % of the respondents, show a more linear demand trend. Farmers in this segment show preferences for trading and are willing to buy more N reduction at each price level than respondents relating to the other two segments. Logistic regression results shows, that the respondents in segment 2 tend to have large total N-caps and small cultivated areas.

Respondents in segment 3 (figure 5D) shows preferences for not trading, but are more price elastic than respondents in segment 1. The possibility of being in segment 3 is larger for respondents with pig production (27 % of the respondents have pig production, 16 % in the demand data) and with low total N-caps.

Aggregated supply (figure 6A) is also inelastic, showing a total supply of 226 ton if the price is 80 DKK/kg. At a price as low as 5 DKK/kg, supply is only reduced to 218 ton N. The total N-cap for the respondents in the supply data is 558 ton, which means that they appear to be willing to reduce their N emissions almost 50 % more than the cap, independent of prices.

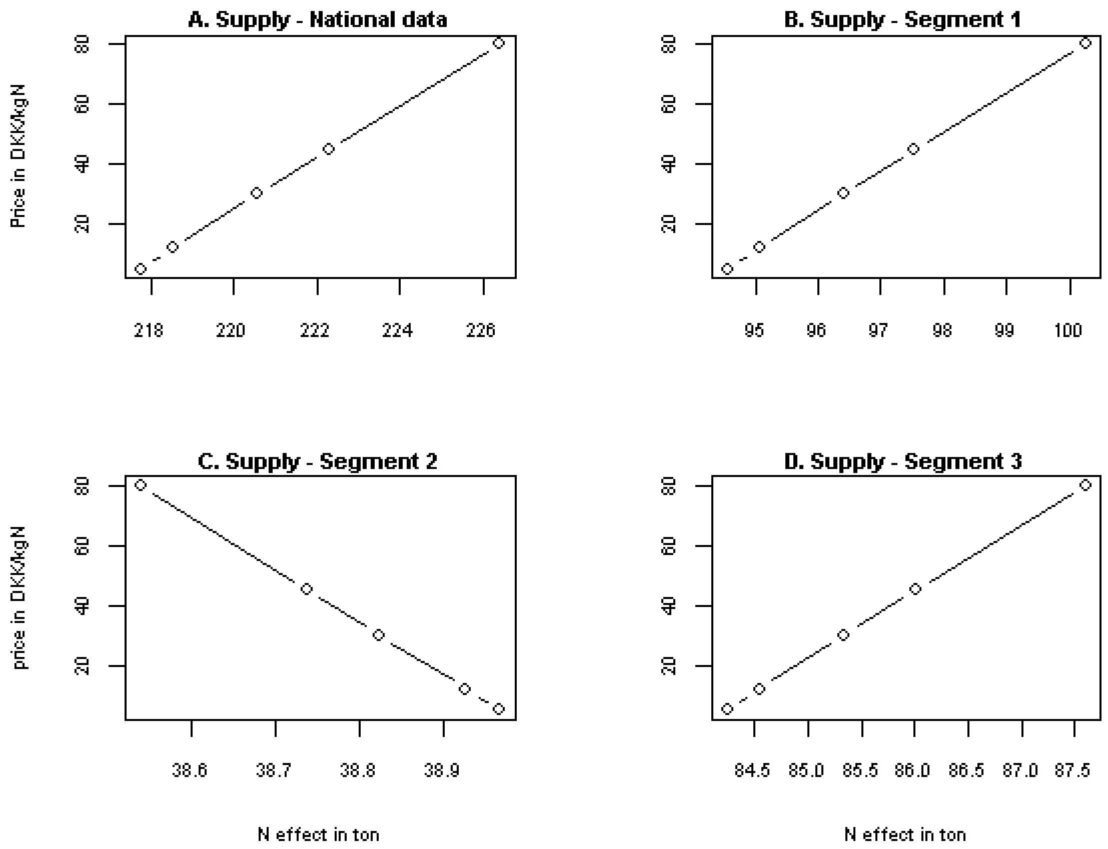


Figure 6: Supply curves for a 3- segment latent class model

From Figure 6 it can be seen, that the supply curves take an inelastic form, especially when studying the different segments. As mentioned, a large part of the alternatives are chosen as opt-outs, which is a part of the explanation. Respondents in segment 1 drive half of the trading-market, supplying 100 ton N at a price of 80 DKK/kg. Respondents in segment 1 cover almost 50 % of all respondents in the supply data. The probability of being in segment

1 is larger for respondents with a large share of their cultivated area being clay soils and with a low artificial drainage percentage. Furthermore they have a large total N-cap and small cultivated areas.

Respondents in segment 2 (figure 6C) cover only 18% of all respondents, and supply in total only 39 ton at all price levels. The opt-out alternative was selected for 16% of all the choice situations. Logistic regressions shows, that the possibility of being in segment 2 is larger for respondents with high N-cap, without animal husbandry (56 % contra 52 % in the supply data) and large areas in cultivation. Notably, segment 2 is very positive towards longer contracts (Table 6) and 47 % of the respondents have more than 2 hectares with forests (27 % for segment 1 and 3).

Respondents in segment 3 (Figure 6D), are almost as price inelastic as respondents in segment 2. Their hypothetical supply only range between 84 and 88 ton N in the different price scenarios. The logistic regressions shows, that the respondents in segment 3 tends to be arable farmers, with a cultivated area larger than 75 hectares, with artificial drained areas and with low N reduction requirement.

4 Discussion

Investigating farmers' trade preferences using a CE methodology has given interesting insights into how farm and farmer characteristic may influence the effectiveness of a voluntary trading scheme in nitrogen abatement. The literature has largely used optimisation-based methods and viewed the policy issue as a social planner's problem. Taking a CE approach has allowed us to investigate individual farmer preferences and determine the extent to which an incentive to trade is likely to emerge. We find that farmers do have preferences for trading N abatement, and that trade can help fulfilling some of the N cap given in the current regulation and eventually improve cost efficiency.

However, the analysis also suggests that a large proportion of farmers choose to opt-out, and the estimated demand and supply curves are very price inelastic. Farmers choose opt-out for different reasons, however, more than 60% of all farmers simply state that they don't want to participate independent of the market price. For farmers choosing supply, 10% gave the explanation that they are not interested in implementing any of the N abatement measures offered in the hypothetical contracts. The choice alternative used for farmers choosing to produce more N abatement than the requirement includes three different measures to choose between; catch crops, energy crops and permanent set aside. However, in a real policy context, N abatement could be obtained from a wide range of measures and in different combinations. Given the choice design we cannot rule out that farmers chose to opt-out, because they don't want to implement any of the offered measures not because they don't see an economic advantage in supplying N abatement to the market. The estimated supply might therefore be underestimated. This relate to a discussion brought up in previous research debating whether the researcher know the bundles of possibilities from which the respondents choose (Adamovicz et al. 2008).

Because of the limited size of the data set, partly due to the opt-outs, we have not been able to conduct the analysis at catchment scale. Instead, data is used to analyse preferences across farm and farmer types, independent on geographical location. Even so, this gives useful insight into who are willing to trade and analysis of how markets would operate if designed to reallocate N abatement within catchments.

We find that more respondents in the catchments areas with high abatement requirements are interested in buying N abatement on the market than selling, while more are interested in selling N abatement in the low-requirement catchment areas. This was expected, because the high N abatement requirement forces farmers to make significant changes on their farm at high costs. Our findings indicate, that in areas with a high N abatement requirement, a market may be difficult to establish. This is because of the uneven distribution of farmers willing to sell and buy N at the market, which eventually drive up the market prices. Furthermore, larger farms tend to be more interested in buying N abatement, while smaller farms tend to be more interested in selling N abatement. This is an intuitive result, as the larger farms tend to be more intensive, and therefore can make more profit from paying others to abate. Another characteristic is that farms with pig production tend to be more willing to buy N at the market. An explanation could be that pig producers are very intensively producing farms with a large requirement for area for spreading manure, and therefore could benefit from the market. Heterogeneity among farmers is therefore crucial for the market to operate within an area.

Furthermore we found, that farmer heterogeneity influences the demand and supply functions. Three segments were discovered in each of the demand and supply groups, each with a different function and different characteristics. If catchments are homogeneous there is little incentive to reallocate abatement effort between farms. In a country like Denmark, where most part of the husbandry are located in catchments in Western Denmark (Statistics Denmark 2015), the homogeneity in farm type could potentially limit the potential in a trading scheme. In other locations where the trading catchments appear to be larger, e.g. the Boone River watershed, Iowa, US, as studied by Kling et al (2011) and Rabotyagov et al. 2013, this kind of trade could potentially solve a large share of the N abatement target.

The present study suggests that there are limits to the effectiveness of a trading scheme for N abatement, due to the spatial homogeneity of farmers within the catchments. The larger the market, the more likely it is that sufficient variability in productivity and farm objectives will stimulate trade. A trading scheme would also tend to be more effective if the within catchment differences in N retention capacity was taken into account. In the current regulation the N reduction requirement is considered constant within a catchment.

However, in reality the retention within a catchment can differ substantially. This means that farmers fulfilling their N abatement based on an average retention, but actually has a higher than average N retention, will provide less abatement than the scheme would estimate. Reversely, if the retention on the farmers land is lower than the average retention, he/she will abatement more than the scheme would indicate. The variability in N retention could be utilised in a trading scheme by taking retention into account in the policy design, i.e. letting farmers trade based on the abatement achieved in downstream freshwater and marine ecosystem.

5 Conclusion

Degradation of water ecosystem caused by excessive loads of nutrient from agriculture continues to be a daunting problem in many countries. Targeted regulation have been motivated from both environmental and economic rationales, and based upon a range of different target-parameters. Most important for the targeted regulation of N emissions, is that the N abatement required to obtain an N reduction target in a water catchment basin, need to be conducted in the specific catchment area and cannot be substituted with N abatement actions elsewhere. Achieving cost-efficient implementation of N abatement actions may depend on farmers' response to the policy incentives. In this paper we have presented a method for analysing farmers' preferences for participating in a cap and trade system for N abatement. The results can be used to support the design of policy incentives used to address nutrient reductions. Our results suggests, that farmers imposed to high N abatement requirements are more willing to purchase N at the market than farmers in areas with low N abatement requirements. This was expected. However, within the group of farmers willing to trade N abatement, we find a high level of heterogeneity. Our results therefore indicate, that a market for N trading to reallocate N abatement between farmers, are more likely to operate if there exist large heterogeneity among farmers within the market. If the market is homogenous due to farm and farmer characteristics, there is little incentive for the farmers to trade as the homogeneity drives up market prices. However, in this study we do not take into account that the effectiveness of N abatement measures vary within catchments. If the within catchment differences in N retention was taken into account, introducing more heterogeneity, a trading scheme would tend to be more effective. While much work remains in this area, the method presented in this paper can be used to investigate markets for N trading between farmers and support future designs of trading schemes. The obtained knowledge on farmer preferences for trading and the revealed demand and supply functions, can be used to upscale the trading behaviour. This would allow us to simulate a disaggregated market based on catchment level N reduction target and reveal the market equilibrium prices and N amount. Coupling revealed demand and supply functions for different segments of farmers' typologies, with catchment characteristics based on agricultural databases, could prove a powerful tool for testing different trade schemes designs

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