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Danish farmers' preferences for bio-based fertilisers – a choice experiment

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Abstract

Within the transition towards a "circular" economy, more farmers are searching for bio-based fertilisers, which are nutrient products based on animal manure. In Denmark, there are many collaborative agreements between farmers, and the need for manure processing is relatively low. Arable farmers typically receive the manure free of charge or for a relatively low cost (application or transport costs). However, Danish farmers might want to buy bio-based products from e.g. the Netherlands instead of mineral fertiliser depending on the product and the price. The purpose of this paper is to investigate how much Danish farmers are willing to pay for bio-based fertilisers and what characteristics of bio-based fertilisers are the most important for the farmers to start using them. We use the stated preference technique of a Choice Experiment, and present respondents with a choice between two bio-based fertiliser alternatives and their current mineral fertiliser, where the alternatives are characterised by selected fertiliser attributes. Data was collected from 202 Danish farmers. Results indicate that the farmers prefer a higher certainty in the N-content, low volume, organic carbon and hygienisation. The ideal bio-based product, which is like mineral fertiliser, but also includes organic material, typically can be sold at up to 50% of the mineral fertiliser price. The analysis also shows that some farmers are unlikely to accept bio-based fertilisers unless the product has the same properties as mineral fertilisers.

Keywords: Bio-based, manure, fertiliser attributes, willingness-to-pay, choice experiment

1. Introduction

Many European farmers have agreements with neighbouring farmers regarding the distribution of animal manure (Asai et al. 2014; Jacobsen 2017), which offers them a degree of certainty regarding their export options. This allows for an easy and efficient use of the animal manure. Within the EU focus on a "circular" economy, there is a further focus on ensuring that manure is used as efficiently as possible. Farmers in very livestock intensive areas such as the Netherlands and Flanders import a large amount of mineral fertilisers. At the same time, they export manure to France and Germany, which may involve costly processing before exporting. In general, processing manure will add a cost to the product which is produced, but will make it cheaper to transport over a longer distance. Most farmers will therefore aim for the lowest cost option, which is to distribute untreated manure on their own farm or a farm nearby. Environmental regulations such as the nitrate directive and the maximum application of 170 kg N per ha ensures that manure is spread over a larger area in most cases. Furthermore, a limit on the phosphorus application per ha might set a limit as seen in the Netherlands and in Denmark, where new phosphorus limits were introduced from August 2017. However, in livestock intensive areas, not enough area is available so either higher compensation is given to arable farms not so interested in receiving manure, or the manure has to be processed and exported further away. In the Netherlands, the regulation also requires that a percentage of the manure equivalent to the phosphorus surplus must be processed (Jacobsen 2017). In 2017 this share can be 10-59% of the surplus depending on the region and 25% of all manure is processed (Jacobsen 2017). The processed manure product will then be directly competing with mineral fertiliser in a number of regions outside the livestock intensive areas

However, little is known of the value which the farmer places on the various attributes of the manure. The current acceptability of animal manure from livestock as a replacement for mineral or artificial fertiliser is indirectly described in the prices livestock farmers pay to export manure. In Flanders and the Netherlands farmers have to pay 20-40 € per tonne to send it to a processing plant and around half of all slurry is processed (separated and made into various products) and around 25% is then exported to Germany or France (Jacobsen 2017; der Straeten et al. 2011; Grinsven 2012).

In half the cases, the Danish livestock farmer pays for transportation and application of slurry, and in the other half of the cases the arable farmer pays for both transportation and application (Knudsen 2016). The amount of slurry being separated in Denmark is much lower (<3%) than in the Netherlands and in Flanders (Jacobsen 2011). Even though many Danish farmers have agreements regarding selling or transporting slurry to neighbouring farms, not all farms are willing to receive organic manure for various reasons and some only want to receive bio-based fertilisers if they have certain attributes.

In Denmark, under 3% of the total amount of slurry is separated into a thick fraction and a liquid fraction, whereas this share is 8% at the EU level (Case et al. 2017). Some of this separation happens in relation to biogas production. In 2014 around 7% of the slurry in Denmark was processed in a digester in order to produce biogas (Jacobsen et al. 2014), but the share has increased and it is estimated to be close to 15% in 2017 (DCE 2016).

Other analyses show that Danish farmers are interested in using more processed manures and urban waste-derived fertilizer than they do now (Case et al. 2017). A large percentage (40%) of farmers did not have access to processed forms of organic fertiliser, particularly PRO (35% of respondents). Case et al. (2017) also states that farm and farmer characteristics such as farming activity, farmer age, farm size and conventional/organic farming influenced the likelihood of future interest in alternative organic fertilisers. The most important barriers to the use of organic fertiliser identified among respondents were unpleasant odour for neighbours, uncertainty in nutrient content and difficulty in planning and use. Improved soil structure was clearly chosen as the most important advantage or reason to use organic fertiliser, followed by low cost to buy or product, and ease of availability (Case et al. 2017).

In our paper, we use the term bio-based fertiliser to refer to different types of fertilisers based on organic manure, which can therefore be products from different types of separation, digestate from biogas plants or products which are processed further (e.g. Struvite or concentrate N). All these types of fertilisers are, in this paper, included in the term bio-based fertiliser, whereas the term animal manure covers non-processed manure. Many farmers use a combination of mineral fertiliser and animal manure, when available, in their fertiliser practices. Acidification of slurry is not included as a bio-based fertiliser in this case.

Following a change in the Fertiliser Directive (EU no. 2003/2003), EU-countries like Belgium and the Netherlands are currently hoping to be able to apply mineral concentrates based on the liquid manure fraction instead of synthetic fertiliser. The mineral concentrates will have properties which are similar to synthetic fertilisers and the application will not be limited by the Nitrate Directive. In the case of this being allowed, it would be interesting to see what farmers would pay for such a product also in Denmark.

One of the Danish policies in relation to nitrogen application has been the introduction of Nitrogen norms, which set a limit for the nitrogen used for a selected crop. The N-quota covers both mineral fertiliser and the organic manure (Dalgaard et al. 2014). The N-quota, in Denmark, has for some years been below the economic optimal level and so the value of the last applied kg of N is higher than the price of mineral fertiliser. Analyses indicate that the shadow value of N in wheat is close to 2 €/kg N, whereas the retail price on N is 1.1 €/kg N. Furthermore, the utilization requirement in Denmark regarding the use of N in organic manure is one of the highest in the EU (Webb et al. 2013). Therefore, Danish farmers are very much aware of the N-content in the slurry they receive from other farmers and they are perhaps more reluctant to receive manure, especially if the content is uncertain. This below-optimal N-quota has been abandoned from 2016/2017 and may result in farmers lowering their requirements of a bio-based product as the change will reduce the value of the last kg N.

The purpose of this paper is to extract knowledge about Danish farmers' willingness-to-pay (WTP) for bio-based products, differentiated according to properties such as form, volume, certainty in N-content as well as the presence of organic carbon and hygenisation. This could be products based on Danish manure, but could also be bio-based products produced in e.g. Belgium and the Netherlands. Our paper is innovative as it tries to link WTP estimates to bio-based manure and the manure regulation, using Denmark as a case and looking at different products. In recent papers (Case et al. 2017; Hou et al. 2018), farmers' perception of organic waste products in Denmark has also been discussed, but not valued as is done in our analysis. By using a Choice Experiment approach we hope to get deeper knowledge of which attributes are most important, as well as what farmers are willing to pay for bio-based products based on different attributes. By estimating prices for different products, it also allows for a discussion as to whether it is possible to process manure and create the product at a price which farmers are willing to pay.

2. Methodology

We elicit Danish farmers' preferences for bio-based fertilisers using the stated preference technique of a Choice Experiment (see Adamowicz et al. 1998). The survey used in the present study elicits preferences for changes in attributes relating to bio-based fertilisers. Prior to the choice sets, the respondents were presented with a scenario description, introducing seven different attributes of the bio-based fertilisers: form, volume, uncertainty about N-content, presence of organic carbon, presence of pests and diseases, as well the speed of nutrient release. These attributes and their levels were identified firstly by interviews with experts, then at stakeholder meetings and interviews with farmers (Tur-Cardona et al., 2018). The form attribute is important for the machinery used and the application rate. The N-content is important, especially if there is a limit, but also to apply the expected amount of N to a given crop. Reduced volume will reduce the transportation costs. The share of organic carbon gives an idea of the amount of carbon added to the soil, and the speed of the nutrient release indicates when the N is available. Pest and deceases are included in relation to hygienisation when exporting to other countries. Livestock manure is distributed to EU-member states under Animal by-product regulation (EU 1069/2009 and EU 142/2011) where the prevention of (animal) diseases is essential and a sanitation by heating (1 hour at 70° Celsius) is required (Bral et al. 2015). The odour of the product was also suggested as an attribute, but most of the interview and meeting participants did not find the attribute to be important.

A percentage reduction in the bio-based product price compared to the respondents' present chemical fertiliser price was used as the level of payment that the farmer is willing to pay. The attributes were presented to the respondents with the descriptions shown in Table 1.

Table 1. Attributes and attribute levels

Attributes	Attribute levels
Price	Same as artificial fertiliser
	20% cheaper
	40% cheaper
	60% cheaper
Form	Liquid
	Granulate
	Semi-solid
	Combination of liquid and solid
Advised volume of bio-based fertiliser needed compared to artificial fertiliser	Same as current artificial fertiliser
	×2 volume
	×4 volume
	×6 volume
Uncertainty about the N-content	Certainty about N-content
	Possibly 25% variation in N-content
	Possibly 50% variation in N-content
	Possibly 75% variation in N-content
Organic carbon	No organic carbon
	As much organic carbon as in straw-containing stable manure
Pests and diseases	Not made hygienic
	Made hygienic
Rate of nutrient release	Slow
	Fast

Note: 'Made hygienic' in this case does mean that the manure can be exported across borders.

A statistically efficient choice design combining the attribute levels shown in Table 1 into alternatives and choice sets was constructed using Ngene, a software for designing choice experiments (ChoiceMetrics 2012). Figure 2 shows an example of a choice set used in the questionnaire. It should be noted that along with the two bio-based fertiliser alternatives, the respondents were also given the option to opt-out and instead choose their current fertiliser.

	Bio-based fertiliser A	Bio-based fertiliser B
Price	Same price as artificial fertiliser	40% cheaper
Form	A combination of liquid and solid forms	Liquid
Advised volume of bio-based fertiliser needed compared to artificial fertiliser	2x volume	Same volume as current artificial fertiliser
Uncertainty about the N-content	Possibly 50% variation on N-content	Certainty about N-content
Organic carbon	No organic carbon	No organic carbon
Pests and diseases	Not made hygienic	Made hygienic
Speed of nutrient release	Slow	Slow

Please indicate the fertiliser that you prefer:

- ❍ Bio-based fertiliser A
- ❍ Bio-based fertiliser B
- ❍ Current artificial fertiliser

Figure 2. Example of a choice set.

2.1 Choice model specification: Latent class model

Latent Class Models account for the heterogeneity in preferences among respondents by dividing them in groups or classes (McFadden and Train, 2000). The fundamental theory of this model suggests that individual behaviour will depend on the described attributes and on a latent heterogeneity defined by unobserved factors. The differently described groups, each defined by relatively homogeneous preferences, capture the heterogeneity of preferences. By allowing a different number of classes, the heterogeneity in preferences can be ascribed to the different groups. The membership to a specific group is related to the attitudes or the characteristics of the respondents (Birol et al. 2006).

The standard Latent Class Model specification assumes a random utility model, where according to Greene and Hensher (2003), an individual *i* will obtain the maximum utility from selecting an alternative *j* at choice situation *t* given the class *c*:

$$U_{jit}=\beta_c' x_{jit} + \varepsilon_{jit} \quad (1)$$

The first part of the equation relates to the specific attributes (β_c) and the second captures the attributes and characteristics of the utility function. The optimal number of classes is formed based on the pseudo-R^2, Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) (Colombo et al. 2009; Ruto et al. 2008).

Two groups without class specific variables were formed. Once the groups are formed, information about the different groups can be examined to better define the formed groups. To identify significant differences between the distribution of the groups and the general sample, Chi-square tests and T-tests were used.

2.2 Calculating WTP

By including price as one of the attributes, estimates of WTP can be inferred for different attributes. The price attribute is considered as a continuous measure despite it being introduced in the alternatives as four values representing a percentage reduction compared to the price of the opt-out (artificial fertiliser). The mean WTP measures were calculated simply by dividing the average coefficients obtained for the different attributes by the coefficient for the reduction of price:

$$WTP = \frac{\beta_{attribute}}{\beta_{\ price\ reduction}} \quad (2)$$

3. Results

Data was collected as part of the EU project INEMAD (Improved Nutrient and Energy Management through Anaerobic Digestion) which aims to reconnect livestock and crop production so the Danish results can be compared with the European results (Tur-Cardona et al. 2018). Our survey methods consisted of both online and postal. Addresses were sampled from a group of Danish farmers used in different projects (Asai et al. 2014; Case et al. 2017). From this group, a sub-group, which has used imported animal manure, was extracted, and the final respondents were randomly sampled from this sub-group. This was done as the focus of the analysis was on farmers who receive manure, and as such, our final sample will contain considerably more arable farms than the Danish average. The online questionnaire was sent to 5,000 farmers and the postal questionnaire was sent to another 2,000 farmers.

A total of 202 responses were received from Danish farmers. Of these, 110 (54%) of responses were received through the online survey, while the rest (92) were collected with the postal survey. The low response rate in this survey (2.9%) can be explained by several factors. A key factor is that Danish farmers are not familiar with the term bio-based fertilisers as they mainly use manure from neighbours. It is not uncommon that the survey method Choice Experiments are found to be more difficult as they often take longer to answer than a regular survey. A higher response rate of 28% was achieved in a similar Danish questionnaire (Case et al. 2017), but their survey was more focused on Danish conditions and had a considerably shorter questionnaire without a Choice Experiment. It is likely that farmers with an above-average interest in future manure products will be more interested in participating in this survey, but this has been difficult to assess in greater detail.

3.1 Descriptive Statistics

The overview in Table 2 shows that farmers in the sample primarily are arable farmers who use mineral fertiliser and animal manure. Compared to the average full time Danish farmer in 2013, the farmers in the sample have about the same ages as the Danish average and the farm size is also the same. Their share of processed manure is close to the average.

Table 2. Comparison between sample farmers and average Danish full-time farmers in 2013.

	Sample (n=202)	Danish average (full time)
Age (years)	55[a]	52
Size of farm (ha)	144	160
Owned (ha)	107	109
Share of manure processed (%)	3-4%	3%
Arable farms (%)	79%	22%

Source : Statistics Denmark (2014) and own calculations

Note: The age of the sample is calculated assuming that respondents over 50 years old (the highest age group answer possibility) are all 60 years old.

3.2. Latent Class

As shown in Table 3, the expected signs are observed, in that attributes expected to contribute positively to utility have a positive sign in their WTP and vice versa. According to rational choice theory, we would expect that farmers will pay more for products which have attributes that they prefer. In Table 3, WTP estimates are expressed as a percentage of the mineral price of N. For the full Latent Class model estimation results including the membership function, please refer to Table B in the appendix.

Table 3. WTP estimates expressed as a percentage of the mineral price of N [lower 95% confidence interval, upper 95% confidence interval]

	ALL		Class 1 "The young and interested" (0.67)		Class 2 "The older and not interested" (0.33)	
Granulate vs S-L	***15.34****	***[9.2, 21.5]***	***16.3****	***[9.1, 23.4]***	8.8	[-8.7, 26.2]
Liquid vs S-L	1.18	[-7.0, 9.4]	-0.4	[-11.0, 10.1]	4.9	[-13.6, 23.4]
Semi-solid vs S-L	0.67	[-6.5, 7.8]	-0.8	[-9.7, 8.1]	-0.9	[-16.6, 14.8]
Higher volume (x2)	***-3.68****	***[-5.8, -1.5]***	***-2.9****	***[-5.5, -0.3]***	***-6.6****	***[-12.0, -1.2]***
Uncertainty N (%)	***-1.06****	***[-1.2, -0.9]***	***-1.2****	***[-1.4, -0.9]***	***-1.2****	***[-1.7, -0.6]***
Organic C	***9.95****	***[-15.3, -4.6]***	***8.6****	***[17.3, 2.5]***	***19.1****	***[36.1, 2.1]***
Hygienic	***14.67****	***[9.4, 19.9]***	***11.5****	***[5.4, 17.6]***	***29.8****	***[13.3, 33.2]***
Fast nutrient release	0.07	[-2.4, 7.6]	-3.9	[-9.5, 1.7]	***25.7****	***[11.1, 40.2]***
Current fertiliser	***-13.79****	***[1.1, 26.4]***	***+14.9****	***[-30.4, 0.6]***	***-33.8****	***[4.9, 62.7]***

Note: * indicate significance at 10% level.

The positive sign on the price reduction indicates that a reduction in price contributes positively to the respondents' utility in accordance with basic economic theory. The WTP estimates denote the sample average WTP associated with a change from the status quo (current fertiliser). All the bold and italic values in Table 3 are significant values. The results displayed in Table 3 show that there are two classes in our sample of farmers, where the classes were found based on the use of a membership function The purpose of the membership function is to divide the sample into groups based on significant attitudes and characteristics[2]. The first class represents 67% of the farmers while the second class contains 33% of respondents. Both classes show a preference for reducing price, uncertainty in the nitrogen content and volume of fertiliser required.

It can be noted that the Class 2 farmers have a lower negative value for higher volume and they are very positive towards attributes like hygienic and fast release. The coefficient for the current fertiliser for the Class 2 farmers has a negative sign, which suggests that respondents in this class have a preference for staying with their current artificial fertiliser. We choose to call the Class 2 farmers "older and not interested"[3]. The WTP estimates for these farmers show that they would require a large price reduction of almost 50% compared to the price of their current fertiliser before they would use bio-based fertilisers as indicated by the WTP estimate for the current fertiliser (49.3%). Conversely, the Class 1 farmers appear to have a positive perception towards alternatives to their current fertiliser as indicated by the positive sign for the current fertiliser coefficient, thereby indicating that respondents in this class have a preference for one of the bio-based fertiliser alternatives. The Class 1 is therefore called the

[2] The specifics of the latent class model and the membership function are available from the authors upon request.
[3] See table 4.

"young and interested". Other differences between the classes include the Class 1 farmers having a significant preference for the granulate form.

Turning to a comparison of respondent characteristics across classes, Table 4, shows that there are some differences in the farmers' characteristics among the two groups.

Table 4. Description of the differences between the two generated classes.

Question		Sample	Class 1 (33%)	Class 2 (66%)
Age*	20-30	1 %	1 %	0
	30-40	7 %	10 %	3 %
	40-50	22 %	25 %	15 %
	>50	70 %	64 %	82 %
How much land owned?*	Owned	107 ha	119 ha	83 ha
How much land do you rent?*	Rent	18 ha	22 ha	13 ha
What kind of soil?***	Sandy soil	37 %	39 %	30 %
	Mix of sandy and clay soil	45 %	49 %	38 %
Have you experienced that the fertilization seemed insufficient after the use of animal manure?***	Yes – NPK	43 %	50 %	26 %
	Yes - Micronutrients	1 %	1 %	0 %
	No	57 %	49 %	74 %
Are you interested in using bio-based fertilisers in the future?	Digestate***	20 %	28 %	4 %
	Ammonium sulphate***	17 %	23 %	2 %
	Struvite***	17 %	23 %	0 %
	Concentrated manure*	20 %	24 %	8 %
	Biochar	28 %	38 %	18 %
	Other (e.g. compost)***	10 %	15 %	0

Note: ***, **, * indicate significance at 1%, 5%, 10% level, respectively across the two classes.

Differences are found in the age, average area of the farm, type of soils, experienced deficiencies in fertilization with manure and interest in fertilisers in the future. Class 1 are the younger farmers who are more interested in using bio-based products. Class 2 represents a smaller class with less interest in bio-based fertilisers, as indicated by their preference for the current fertiliser and also as stated when asked about the interest in different bio-based fertilisers. Class 1 is represented by younger farmers with larger extensions of owned and rented land. This class, despite not using bio-based fertilisers at the moment, shows more interest in using them in the future. Farmers, who in the past experienced deficiencies using manure as fertiliser, are more likely to be in this group. In this case, farmers may believe that the processing will reduce these deficiencies. Thus, farmers would attach some value to the reduction of N content uncertainty and also attach some value to a granulate form of fertiliser which is easier to distribute.

3.3. Willingness-to-Pay (WTP)

Based on the results in Table 3 it is now possible to calculate the WTP for predefined products as shown in Table 5.

Table 5. Price of N for different bio-based products compared to mineral fertiliser and organic N in Denmark. (% of mineral N price)

		Bio-product 1	Bio-product 2	Bio-product 3 (optimal product)
Desc. of the product		Granulate, x7 volume, 10% uncertainty, with organic carbon	Granulate, x4 volume, 5% uncertainty, with organic carbon	Granulate, x1 volume, no uncertainty, with organic carbon and fast release of nutrients
All	Attributes	-11.10	19.91	39.95
	+current (-13.8 %)	***-24.9***	***6.13***	***26.16***
Class 1	Attributes	-7.01	18.95	36.32
	+current (+14.9 %)	***7.85***	***33.81***	***51.19***
Class 2	Attributes	-38.6	16.75	74.6
	+current (-33.8 %)	***-72.45***	***-17.1***	***40.8*** *)

Note: The cost of application of slurry is 10 DKK per ton and with 5 kg N per ton, which is around 2 DKK/ kg N. Application of mineral fertiliser is around 1.1 DKK/kg N. In the questionnaire, it was indicated that this cost should be included in the values so the value was N applied on the field.

*) Without the fast nutrient release attribute for Class 2 farmers (25.7 % in Table 3), the WTP for the whole sample (all) would be in the middle of the two groups (Class 1 and 2). The result comes as the attribute (fast release) has a large effect only included for the Class 2 farmers.

The three products chosen are named Bio-product 1, 2 and 3. Bio-product 1 has properties similar to slurry, but in a granulate form; Bio-product 2 is also granulate, but with lower volume and still some uncertainty; Bio-product 3 has all the positive properties including granulate, the same volume as mineral fertiliser, with no uncertainty and with organic carbon. In other words, Bio-product 3 is a mineral fertiliser based on manure and with organic properties. The price all farmers are willing to pay has been calculated based on the WTP for the attributes shown in Table 3, which is then adjusted according to the preference farmers have with respect to their current mineral fertiliser, in that the values of the attributes plus the current fertiliser value is the actual price farmers are willing to pay.

Table 5 shows that the average farmer will not pay for Bio-product 1. Class 1 farmers will pay 8% of the mineral price, but Class 2 farmers will not pay for this product. For Bio-product 2, the average farmer is willing to pay 6% of the average mineral fertiliser price. The Class 1 farmers will pay a little more than 33%, but the Class 2 farmers are not willing to pay for this product. Finally, Bio-product 3 can be sold at 26% of the mineral fertiliser price to the average farmer. It is noticeable here that the Class 1 farmers are willing to pay 51%, but now the Class 2 farmers are willing to pay 41% of the mineral fertiliser price. It should be noted that without the fast nutrient release attribute for Class 2 farmers (25.7%), the WTP for the whole sample (all) would be in the middle of the two groups (Class 1 and 2). The result comes as the attribute fast nutrient release has a large effect only on Class 2 farmers.

4. Discussion and conclusion

This paper has investigated Danish farmers' Willingness-to-Pay (WTP) for bio-based products. We analysed a dataset consisting of 202 Danish farmers who answered a Choice Experiment questionnaire, where they were asked to choose between their current mineral fertiliser and bio-based alternatives. The farmers participating are perceived to be close to the average Danish farmer receiving manure from livestock farms today. The sample consisted mainly of arable farms.

The data was analysed using a Latent Class Model approach resulting in two distinct classes of Danish farmer in terms of their preferences. WTP for the bio-based fertiliser was estimated in terms a percentage of the price of the current mineral fertiliser. Our results indicate that the WTP for the most optimal bio-based product with all the preferred attributes will be 51% of the mineral fertiliser price for the Class 1 farmers, while for the Class 2 farmers, the value is 41%. Class 1 farmers show a preference for the granulate form of fertiliser, presence of carbon and hygienization of the product, with a relative positive perception (around 25% in table 4) toward an alternative bio-based fertiliser. Given the perception of bio-based fertilisers by Class 2, only a hygienic product with fast release will result in a product that farmers in this group will accept to pay for. The young farmers in Class 1 will be more willing to buy different bio-based products from e.g. Belgium and the Netherlands.

When comparing our sample of Danish farmers to other EU farmers using the data Tur-Cardona et al. (2018), we see that the Danish farmers stand out as they choose their current chemical fertiliser in more cases than in other countries (43%) as opposed to 16-30% in six other EU countries. This can be explained by the different policy options implemented in the past and the different technological solutions farmers are exploring in the Danish context. The focus in Denmark has been on policies which impose a strong restriction on the number of animals, reducing the problem of nutrient surplus and where the utilisation requirements are high. Our Danish farmer results indicate a relatively low value attached to the nutrients in bio-based fertilisers even with hygienization, presence of organic carbon, certainty in the content and concentrated volumes.

It has not directly been a part of this paper to investigate the costs of processing manure in order to produce the bio-based products with the properties described in Table 5. However, it is relevant to link the prices farmers will pay with a calculation of the required processing cost. For processing plants to be able to deliver a bio-based product at around 50% or 0.5 € per kg N in the field, they are likely to have to be paid to receive the manure, as is the case in the Netherlands and Belgium (Jacobsen 2017). In these countries, the processing plant receives up to 20-30 € per ton (4-5 € per kg N) with the slurry and so it is probably possible to sell the product at e.g. 50% of the mineral fertiliser price. The processing costs could then be around 5 € per kg N.

In the Danish case, where the processing company would receive the slurry free of charge or for a low fee (e.g. up to 5 € per ton of slurry or 1 € per kg N), it is less likely that the processing company could sell the best products at 0.5 € per kg N as it would only leave a maximum of around 1.5 € per kg N (or 7 € per ton of slurry) for the processing. Our analysis indicates that the economic options for carrying out processing are better in the Netherlands and Belgium than in Denmark given the current manure market. However, Danish farmers would, given the prices above, be willing to import bio-based fertiliser from e.g. the Netherlands.

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