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Livestock farmer perceptions of successful collaborative arrangements for manure exchange: A study in Denmark

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ABSTRACT

Fulfilling the targets of the European Nitrate Directive (91/676/EEC) and the Water Framework Directive (2000/60/EC) has required governments to take action to prevent excessive application of livestock manure. In Denmark, where intensive livestock production has caused serious nitrogen leaching to underground water, self-governing manure exchanges have been widely organised among farms in local communities. This allows large livestock farms to achieve the required balance between manure production and the agricultural production area although the importer rarely pays the full nutrient value for the manure received. Despite the potential for improved efficiency of manure use, few studies have examined livestock farmers' perceptions of coordinated arrangements with recipient farms and factors in successful arrangements. A total of 644 manure exporters were asked about factors they consider important in identifying and selecting a new partner for manure export, including factors regarding the potential partner and the function of the partnership. They evaluated a total of 18 statements relating to possible perceptions. The results revealed that exporters appreciated especially four qualities: (1) timely communication regarding establishment of a contract; (2) the potential for a long-term partnership; (3) physical and social accessibilities to the partner/s; and (4) flexibility of acceptance of manure. Multiple regressions were then performed to detect associations between the variables on farm/farmer characteristics and on existing collaborative arrangements, and the factor scores derived from principal component analysis (PCA) of farmers' perceptions. The results provided practical insights into how socio-demographic characteristics of farmers, their production enterprises, their past experiences of transactions and spatial location of farms influenced their decision-making in establishing partnerships. For instance, organic dairy farmers seemed to place less emphasis on the distance to and accessibility of their partner. Exporters on the islands where crop production dominates were significantly more concerned about the characteristics of the partner with respect to his/her professional skills and business expertise. Social aspects, e.g. previous knowledge of the partner, were perceived as more important by older than by younger farmers, while this aspects appeared to be less important for farmers with large business units as their primary aim of making agreements seems to comply with the regulations. These findings are applicable in intensive livestock production areas in other European countries.

1. Introduction

Since 1991, fulfilling the targets of the European Nitrate Directive (91/676/EEC) and the Water Framework Directive (2000/60/EC) has required member states to take actions against excessive application of manure and other fertilisers. The first step includes the identification of areas where groundwater have nitrate concentrations of more than 50 mg/l nitrate, and this knowledge is used to find the area which, as a minimum, should be designated as Nitrate Vulnerable Zones (NVZs) (DEFRA, 2009; Macgregor and Warren, 2006; Smith et al., 2007; van Grinsven et al., 2012). Farmers with land in NVZ must adhere to strict rules over the timing and application of nitrogen from organic and inorganic sources (Barnes et al., 2009). In Denmark, intensive livestock production has caused serious nitrogen leaching to underground water reserves at national scale (Kronvang et al., 2008). The Danish government, along

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with a number of other European countries (Finland, Ireland, Lithuania, Luxembourg, Malta, The Netherlands, Slovenia, Germany and Austria), has thus adopted country-wide designations, implying that as a starting point, all farmers must follow the same regulations regardless of regional variations in production environments and socio-economic conditions. Currently each Danish livestock holding must ensure a balance between agricultural land and the number of livestock units corresponding to a maximum of 170 kg ha^{-1} yr^{-1} of nitrogen from manure for cattle holdings and 140 kg ha^{-1} yr^{-1} of nitrogen for all other livestock holdings, which is stricter than the standard requirements of 170 kg ha^{-1} yr^{-1} of nitrogen from manure in the Nitrate Directive (Mikkelsen et al., 2010). The area included, when calculating the livestock density, can be owned, rented and covered by an agreement, which allows a given amount of livestock manure to be applied. The Danish derogation from the Nitrate Directive permits a maximum of 230 kg ha^{-1} yr^{-1} of nitrogen, and applies to cattle holdings with an average of 90% of agricultural land available for manure application, cropped by crops such as clover grass and other crops with a high nitrogen uptake potential (Commission of the European Communities, 2002; Smith et al., 2007). This regulation has helped to keep the livestock density in Denmark at 1.1 Livestock Units (LU) per hectare, which is somewhat lower than the livestock density in other livestock intensive areas such as The Flanders in Belgium and The Netherlands (Danish Statistics, 2013; van Grinsven et al., 2012). One Danish livestock unit is 100 kg N from the storage and it is currently equal to 0.75 dairy cow or 4.3 sows with piglets up to 7 kg.

The on-going structural change in the Danish livestock sector towards larger farms makes it difficult for livestock farmers to achieve the required balance between the crop area and manure produced at the farm level. This is more severe when coupled with the frequent shortage of available land in livestock-intensive areas. Many livestock farmers thus use the option offered in the regulation to export their excess manure to other farmers. A previous study showed that about 50% of Danish farms were involved in manure exchange and had either exported or imported manure to/from other farms (Asai et al., 2012b). Farmers exporting manure are required to submit information about the manure receiver, including the amount (N kg) and types of manure exported. This information is cross-checked by the authorities in order to ensure that all animal manure is registered and applied correctly. The below economic optimal N-application norm adopted in Denmark means that the costs of fictive manure agreements is relatively high as the total N-application, at the outset, is under the economic optimum. The level of fictive manure agreements in Denmark is perceived to be rather low and so there is no GPS control with manure transport and no official sampling of the nutrient content as is the case in e.g. The Netherlands (Jacobsen, 2011; OECD, 2005; Oomen, 2012).

In other livestock-intensive regions in Europe, various collective actions for handling surplus manure are also being developed (e.g. DEFRA, 2009; Lopez-Ridaura et al., 2009). However, few of these involve such a large population of collaborative arrangements as that in Denmark. The exporters are mainly larger livestock farms (14% of the sample) and the importers (29% of the sample) are mainly arable farms (Asai, 2013). A total of 6% are both importers and exporters of manure. The level of manure export from the farms is also large in e.g. The Netherlands and Belgium (around 50% in The Netherlands), but there, a considerable share is exported long distance and to other countries, which is not the case in Denmark (Oomen, 2012).

Asai et al. (Forthcoming) explored the nature and function of these collaborative arrangements. As regards the objective of continuously reducing environmental impacts, collaborative arrangements on manure exchange have been seen as opportunities for nutrient recycling through the area-wide integration of livestock and crop productions (Entz et al., 2005; Wilkins, 2008). Despite the potential of such arrangements for improved utilisation of nutrient resources, there is a lack of studies providing a more nuanced understanding of livestock farmers' perceptions of successful collaborative arrangements with manure receivers, and the factors they consider important for these. Although these collaborative arrangements are policy-driven, selection of the partner and management of the manure exchange are the responsibility of the individual farmer. Farmers' decisions are adapted to the local production environment and socio-economic conditions (Reidsma et al., 2010; van Ittersum and Rabbinge, 1997). Analyses show that keeping the manure on your own farm is the cheapest option and exporting manure to neighbours often means, that Danish farmers are not paid the full value of the manure (Jacobsen, 2011). In fact, the exporting farmer often has to pay for the transport or the application and he is very rarely paid for the nutrient value of the manure. Buying land is another option, but high livestock intensity often generates high demand, and thereby high prices on land. Arable farms could receive the manure, but they are sometimes reluctant to do so for a number of reasons, such as lack of knowledge regarding nutrient content and the disadvantages of heavy manure application machinery on their fields. Here also the price of mineral fertiliser plays a part as arable farmers are more likely to accept manure and the disadvantages mentioned, if the price of mineral fertiliser is high, as was the case in 2008. The need to export manure is seen in several livestock intensive areas in Europe and has even led to export of manure across borders from e.g. The Netherlands to France and from The Netherlands to Germany.

Hence, it is clear that the way to handle to problem of excess manure is by no means simple for the individual livestock owner. However, the lack of knowledge on the reasoned actions of manure exporters trying to find the most appropriate option means that there are few useful insights for policy makers, farm advisors and researchers seeking to promote collaboration as a way to achieve sustainable nutrient management, on the considerations behind the choice of solutions for manure export, and the weight given to different aspects of the choice of partner.

The present study aimed to provide empirical insights into: (1) what manure-exporting farmers perceive as important for successful collaborative arrangements for manure exchange in addition to direct costs, and (2) how these perceptions are influenced by the local production environment, the individual farm and the production type, as well as the farmers' previous experiences of manure exchange arrangements.

2. Analytical framework

2.1. Theoretical background

In order to understand the farmers' perceptions of successful collaborative arrangements for manure exchange, we found experiences from transaction cost economics (TCE) and organisational theory useful as input to construct an analytical framework. TCE is one of the theoretical approaches within the new institutional economics. With the transaction as the unit of analysis, TCE makes the assumption that there are three types of costs to carry out any exchange (Hobbs, 1997). These include information (or search) costs (*ex ante* costs of identifying suitable exchange partners), negotiating costs (costs of carrying out the transaction, commission costs, costs of negotiating the exchange terms, and costs to make a contract), and monitoring or enforcement costs (*ex post* costs of ensuring that the terms of the exchange are respected) (Hobbs, 1997).

Exchange conditions under uncertainty and complexity increase the transaction costs (Williamson, 2000). Aversion to uncertainty and sources of high risk through greater information sharing between exchange partners can thus be seen as one of the strategies for lowering transaction costs. Studies on organisational theory point out that trust and communication play significant roles in making at least two business partners work collectively to realise outcomes that cannot be achieved alone. The trust relationship ensures that an exchange partner will not act in self-interest at another's expense, and this provides confidence in an exchange partner's reliability and integrity (Morgan and Hunt, 1994), resulting in reduction in the information and monitoring costs. The trust relationship is founded on, and facilitated by, the expectation that each party will pro-actively provide information to the partner (Heide and John, 1992) through frequent, timely, accurate and problem-solving communication (Gittell, 2011). This mutual alignment of trust and communication between partners generates reciprocity and flexibility in exchange relationships. Flexibility can be interpreted here as expectations of willingness to make adaptations (Heide and John, 1992). Flexibility prolongs the stable partnership, and thus saves the costs of searching for a new partner and changing the contract.

In the present study, we assumed that farmers' perceptions of successful collaborations are related to the transaction costs that they face in manure exchange. In other words, the perceptions of manure exporters regarding successful collaborative arrangements can represent their strategies of choosing the best manure receiver and establishing formal arrangements with that receiver through which transaction costs can be minimised. In previous studies, physical market costs such as those for manure transportation and application have been used as main factors for estimating the optimal manure distribution at regional scale (e.g. Aillery et al., 2009; Paudel et al., 2009; Van der Straeten et al., 2010). Hence, the present study included spatial and economic aspects, such as transport distance and cost, but complemented these factors with aspects such as trust, communication and flexibility, as potentially important factors for manure exchange arrangements.

2.2. Farm/farmer characteristics influencing the transaction costs of manure exchange

Transaction costs of manure exchange may be influenced by a range of farm/farmer characteristics, connected to the specific household, to the location or to the type of production (Pingali et al., 2005).

Household-specific characteristics that have been shown to influence transaction costs include variables such as farmer age, agricultural education, farm size, farm type, labour availability and social relations (Pingali et al., 2005). These variables all influence the costs of information seeking, negotiating, monitoring and enforcement in relation to establishing a manure agreement. For instance, age often implies the build-up of farming experience and access to broader farmer networks and local knowledge. This may make identifying suitable partners easier, thereby lowering the information costs. Attaining agricultural education can serve the same purpose. Small farms may be better placed to understand their local environments in a way that ensures the best use of existing resources, and thus the farm size may also potentially influence transaction costs (Pingali et al., 2005). Within the rural community, embedded social networks, related to social capital built upon on trust and communication, play an important role in collective actions (Breetz et al., 2005; Morrison et al., 2011; Pretty and Smith, 2004). The embedded ties offer participants more chances to exclude sources of risks and uncertainty. Collaborative arrangements, such as exporting manure to a well-known neighbour farmer or a partner introduced by local farm advisor, may represent such a mechanism.

Location-specific characteristics make transaction costs vary across locations and regions, and are often related to the distance from animal houses to the fields of manure receivers. The distance travelled during hauling and spreading is the most important variable in terms of the cost of using manure as a crop fertiliser (e.g. Araji et al., 2001). Therefore the accessibility to manure receivers matters in terms of reducing transaction costs. The distance between animal house and manure fertilised field varies depending on e.g. road conditions and road networks (Kang et al., 2008; Paudel et al., 2009) and landscape structure (e.g. landscape fragmentation) (Bartelt and Bland, 2007). Poor road infrastructure or scattered fields at the recipient increase transportation time and therefore costs. Furthermore, in areas with a high density of intensive livestock production units, farms face high competition in gaining access to fields. In theory, this results in longer manure transportation distances than in areas with low livestock density (Aillery et al., 2009). High competition increases the transaction costs associated with the time required to search for partners, and long distance to partners may prevent good communication and thus efficient access to proper information, increasing search and monitoring costs.

As mentioned earlier, at the receiving side, arable farms would gain from receiving cheap nutrients from neighbouring livestock farms, but some find that the costs in terms of uncertainty of nutrient content, application timing, smell and impact of heavy machinery on the soil is higher, which is why they prefer mineral fertiliser (Jacobsen et al., 2002).

Production type-specific characteristics mainly affect transaction costs related to carrying out the export. The economically efficient transport distance of different types of animal manure differs with production type because of the content of dry matter (DM). Dagnall et al. (2000) calculated that high DM manure (~70%) could be viably transported within a 40 km radius of the production site, whereas low DM manure (<10%), typically slurries, could be transported within a 10 km radius. Wilkins (2008) also concluded that relatively dry and energy-dense poultry and pig manures can be transported the longest distance energy-efficiently. However, the results on which distance is economically viable depend on the economic conditions in the country analysed. Danish analyses indicate that most manure is transported in the form of slurry and that the transport distance in most regions is lower than 20 km and the transport of manure with high DM is very limited due to limited manure separation. In Belgium and The Netherlands the use of separation is higher and so is the share of manure exported with a high DM over longer distances.

Not only the livestock type, but also the farming system affects costs. As an example, the value of manure from organic dairy farmers has increased since the introduction of EU regulations requiring organic crop producers to convert to 100% organic manure, resulting in high numbers of arrangements between specialist organic dairy and crop farms (Asai et al., 2012a). However, the 100% organic manure regulation on organic farms is not as yet implemented in Denmark and so organic farmers still profit from making manure agreements with conventional livestock farms of up to 70 kg N/ha. Differences in manure value may alter the costs of carrying out the transaction (e.g. manure transport distance) and the costs of negotiating the exchange terms (e.g. the price and the economic burden sharing of transporting and spreading manure).

Apart from the three types of specific characteristics described above, farmers' previous experiences of existing manure exchange partnerships may influence transaction costs. In general, actors' past experiences of collective action shape the coordination process between partners (Medlin et al., 2005). We also anticipate that up-keeping an existing well-functioning relationship is important

due to the expected lower monitoring and enforcement costs. Hence, the knowledge of a specific partnership from the previous experience, measured in e.g. duration, communication frequency and prior knowledge of the partner, may affect the appreciation of transaction costs.

3. Materials and methods

In order to study farmers' perceptions of successful collaborative arrangement for manure exchange, farmers were asked what they consider important in a situation where they are seeking and selecting a new partner for manure export, and the level of importance they ascribe to the different factors. This regards both the potential partner and the function of the partnership. A questionnaire was designed to reflect the three types of transaction costs (information, negotiating, monitoring/enforcement). Moreover the questionnaire included questions which permitted analysis of the farm/farmer characteristics affecting transaction costs (household-specific, location-specific, production type-specific factors, previous experience-related) in relation to perceptions of successful collaborative arrangements.

3.1. Questionnaire design

The information used for the analyses was obtained using an adapted version of Dilman's tailored design method (Dilman, 2000). First, the questionnaire was designed based on information obtained in phone interviews with five informants to obtain supplementary knowledge on manure management in general and under various local conditions, and about factors influencing involvement in collaborative arrangements. These informants were agricultural advisors, one at the Danish Knowledge Centre for Agriculture and four at local advisory centres.

The questionnaire on manure exporters' preferences when choosing a new partner consisted of two main parts. The first part comprised statements on the importance of partner characteristics such as location of recipient fields, social relations and skills and knowledge of farm management, while the second part referred to the importance of factors related to the function of the partnership, such as ease and frequency of communication, flexibility of manure acceptance and other factors that make the partnership function well and survive for a long period. A total of 18 statements were developed, requiring responses in the form of a five-point Likert-type scale ranging from 1 (not important) to 5 (very important).

The questionnaire also included background questions regarding the farm/farmer characteristics and the nature and function of existing collaborative arrangements. Data obtained through these questions were used as explanatory variables in order to explore how these characteristics influenced the perceptions of successful collaborative arrangements.

3.2. Data collection

A total of 1500 sample farms were identified using the following criteria: (1) farms that were categorised as conventional dairy, organic dairy or conventional pig (no organic pig due to the low population of the group) (see Table 1 and Asai (2013) for details); (2) farms that had exported manure to other farmers during the period 2009–2011; and (3) farms that were located either in livestock-intensive areas or in crop-intensive areas. Farms in Northern and Western Jutland and two islands (Zealand and Funen) were selected to represent these regions, which differs in livestock density - Jutland having the higher livestock density. Information about the farms, including production enterprises, manure types, amounts applied and the farms to which they had exported manure, was obtained from the Danish Fertiliser Account. In 2009, a total of 45,556 Danish farms were registered in the account, and 2880 exporters (2236 farms in Northern and Western Jutland and 617 farms on the islands) qualified as sample farms. Of these, a total of 1500 dairy and pig farms were randomly selected for the survey (Table 1). Due to the low population of organic dairy farms in the islands, organic dairy farms were selected only from Jutland.

Data collection started in December 2012 by sending an invitation letter to the 1500 farmers to complete the online survey, including URL and access code. Ten days later, a reminder postcard was sent by conventional mail. Finally, non-responding farms were sent a follow-up letter and a written questionnaire in January 2013. Farmers who reported that they were no longer active were not replaced.

3.3. Statistical analysis

In order to analyse how the transaction cost-related farm/farmer characteristics (household-specific, location-specific, production type-specific, previous experience-related) affected farmers' perceptions of successful collaborative arrangements, multivariate analysis comprising principal component analysis (PCA) and multiple regression analysis was conducted. All data analyses were undertaken using the R statistical computing software version 2.15.2 (R Development Core Team, 2013).

PCA was applied to the farmers' perception data in order to summarise these into coherent aggregates and to generate factors that were as independent as possible for subsequent use in regressions. Before commencing the PCA itself, the validity of the underlying components was checked through a Kaiser–Meyer–Olkim test (KMO) (Kaiser, 1970), where values >0.6 indicate acceptability. Next, the eigenvalue was computed for each component and the number of factors that best described the data was chosen by selecting only those components with eigenvalue >1. The eigenvalue provides an objective measure of the amount of variation in the original data explained by that component or factor, so this process allowed factors that described a significantly large amount of variation in the original data to be retained. In addition, factor solutions with different numbers of factors were tested before the structures were defined, in order to have the most representative and concise set of factors (Hair et al., 2010). In this application of PCA, the variance contribution of each factor component was extracted using orthogonal (varimax) rotation to obtain factor solutions that were easy to interpret. Standardised factor scores for each farmer and factor were saved for subsequent multiple linear regressions.

Table 1
Sampling statistics and response rates.

	Jutland			The islands (Funen and Zealand)		Total
	Conv. dairy	Conv. pig	Org. dairy	Conv. dairy	Conv. pig	
Exporting farms found in 2009–2011	971	1092	200	190	427	2880
Initial sample	410	400	200	190	300	1500
Total completed	153	181	98	76	136	644
Response rate (%)	37.3	45.3	49.0	40.0	45.3	42.9

Multiple regressions were then used to detect associations between the variables on farm/farmer characteristics and on existing collaborative arrangements, and the factor scores derived from the PCA performed on farmers' perceptions of successful collaborative arrangement. A threshold value of $P < 0.1$ was used for the regression analyses. Simple correlation coefficients between all pairs of independent variables were low. Variance inflation factors were close to 1, suggesting no multicollinearity problems.

4. Results and discussion

4.1. Farm and farmer characteristics

In total, 644 fully completed questionnaires were returned, a response rate of 43% (Table 1). No statistical differences in livestock units and harmony area between respondents ($n = 644$) and non-respondents ($n = 846$) were observed with a two-sided Mann–Whitney U-test.

As seen in Table 1, half of the respondents were dairy farmers (12% from conventional dairy farms in the islands, 24% from conventional dairy farms in Jutland and 15% from organic dairy farms in Jutland) and half were pig farms (21% from conventional pig farms in the islands, and 28% from conventional pig farms in Jutland). Table 2 provides the socio-economic and production characteristics of respondents. The respondents were all full-time livestock producers, aged on average 49 years (range: 26–74) and with an average of 21 years on the farm. Almost all farmers had received agricultural training. Pig farms (mean: 296.0) had significantly ($P < 0.001$) more livestock units (1 LU = 100 kg nitrogen in manure) than dairy farms (mean: 234.5), whereas there were no significant differences between the two regions with varying livestock density. Average farm size was 141.7 ha, including leased land comprising an average of 27% of the total area. This was slightly smaller than the average full time farm in 2011 which had 157 ha and 169 LU (Danish Statistics, 2013). The average for all farms is 78 ha. The farms had an average annual labour unit (man–year) of 3.4. About 28% of respondents reported that they had only one partner as a manure receiver, 24% had two partners and 20% had three partners. The farms had an average of 3.1 partners (range: 1–21).

4.2. Farmers' previous experience of collaborative arrangements

This section describes the nature and function of existing collaborative arrangements. The 644 respondents were asked questions about their previous experience of collaborative arrangements with the primary partner who received the largest amount of manure in 2012. Fig. 1 shows an overview of the 644 arrangements.

The existing partnerships were quite stable over time, as about 70% of partnerships had lasted for more than 5 years, 28% of which for more than 10 years. To investigate the extent to which farmers' collaborative arrangements for manure were local, farmers were asked to estimate the maximum distance between their animal house and the fertilised fields on the partner farm in 2012. About 60% of respondents reported that they transported manure a maximum distance of 1–5 km, while only a small group transported manure more than 10 km. In 79% of the arrangements the manure was given to the partner for free, whereas ways of sharing the economic burden connected with transport and spreading were more varied. In 37% of the partnerships the exporters took on the sole responsibility for transporting and spreading the manure in the partner's fields, in another 37% of the partnerships the importers took on this task, and in the remaining 27% of the arrangements the burden was shared between the partners. Almost all (89%) of the exporters had partnerships with farmers with whom they had one or more types of social relation (e.g. neighbour, fellow member of professional network such as farmers' group, family member) prior to establishing the manure exchange arrangement. The remaining 11% did not know the partner before the partnership was established and thus had been introduced by others. Most exporters communicated with their partner 2–5 times a year (53%), while 38% had contact more than once a month. A previous study showed that in arrangements between family members frequency of communication was high, and the small group (16%) who were in contact weekly to daily mostly consisted of these (Asai et al., Forthcoming).

4.3. Farmers' perceptions of successful collaborative arrangements

Farmers were asked to rate on what they considered important when: (1) Selecting a new partner as manure receiver and (2) maintaining a functioning partnership. A total of 18 statements on farmers' perceptions were evaluated using rank order of the statements along with mean and standard deviation (Table 3).

The statement considered most important was that the partner fulfils the terms of the agreement and the next most important that the partner informs them of any changes in farm management which affect the arrangement, for instance land use change, ahead of time. Timely communication is one of the essential factors in efficient coordinated work (Gittell, 2011), and frequent updates from the partner make it possible for exporters to prepare for a change of contract or to seek other potential partners if necessary. Manure exporters also highly appreciate the stability of a partnership as they identified the solidity of the partner business as an important quality, and as Medlin et al. (2005) points out, confidence in a long term partnership provides motivation to build up a well-functioning relationship.

Table 2
Socio-economic and production characteristics of respondents (mean values).

	Jutland			The islands	
	Conv. dairy	Conv. pig	Org. dairy	Conv. dairy	Conv. pig
Age of respondent	48.6	47.9	50.7	52.0	49.0
Annual labour input	3.2	3.4	2.8	2.8	4.4
Agricultural education (%)	94.1	92.3	93.9	94.7	95.6
Farmland (ha)	132.5	151.7	154.5	111.5	146.5
Livestock units (LU)[a] before export	264.7	300.2	208.5	207.1	290.4
Livestock units (LU)[a] after export	214.2	186.8	187.7	158.2	166.3
Harmony balance (LU/ha)[b] before export	2.12	2.00	1.44	1.92	1.92
Harmony balance (LU/ha)[b] after export	1.65	1.24	1.21	1.44	1.15
Number of manure partners (importers)	2.2	2.5	1.9	2.3	2.4

[a] One LU is equal to 100 kg of nitrogen in manure and the excretion of nitrogen is based on the type of animal and the housing system.
[b] A total of 51 farms were omitted from calculation of LU/ha due to a lack of harmony area (0 ha).

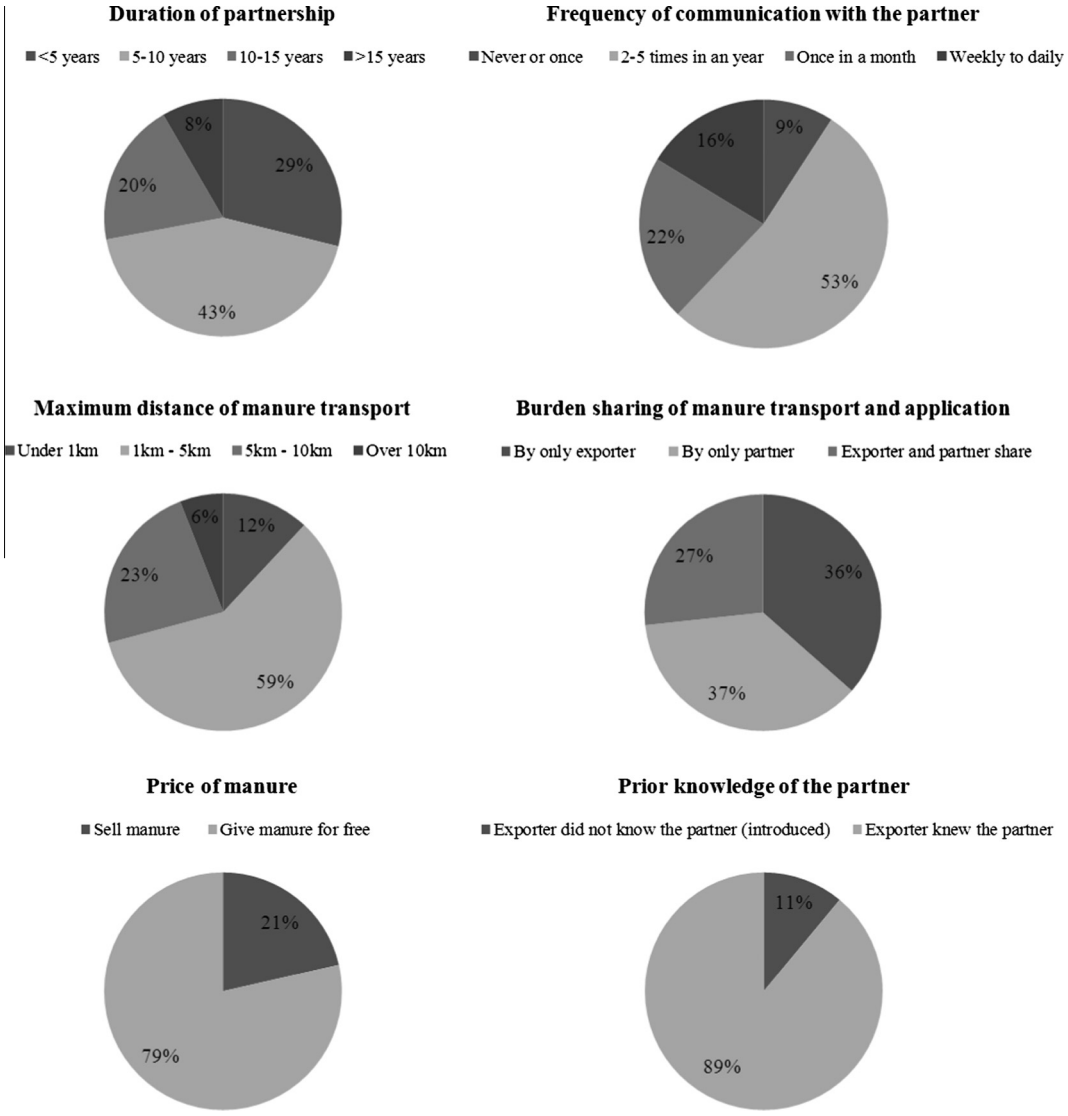


Fig. 1. Overview of existing collaborative arrangements on manure exchange (n = 644).

Table 3
Mean rankings and standard deviation for how statements on successful collaborative arrangement were perceived by manure exporters.

Rank	Statement used for determination of farmers' perceptions when selecting a new partner. How important is it that:	Mean	SD
1	The partner fulfils our agreements[b]	4.54	0.67
2	The partner informs me well in advance of changes which may affect our agreement[b]	4.18	0.79
3	The partner runs a solid business, so the arrangement can be extended[b]	3.71	0.94
4	Fields of partner are located close to my animal houses[a]	3.48	1.10
5	The partner is flexible as to when he receives the manure[b]	3.41	0.91
6	Fields of partner are easy to access[a]	3.34	1.11
7	The partner is a person from the local area[a]	3.24	1.30
8	The partner is easy to get in touch with[b]	3.06	1.01
9	The partner is flexible in relation to the amount of manure[b]	3.01	0.94
10	Fields of partner are aggregated and not dispersed[a]	2.96	1.13
11	The partner is a person I already know[a]	2.83	1.21
12	The partner is flexible and will accept manure outside the agreed period if I have a problem with storage capacity[b]	2.75	1.13
13	The partner runs a professional farm business[a]	2.65	1.15
14	The partner is well informed about environmental regulations and subsidies[a]	2.57	1.08
15	The partner is a competent farmer in his/her specialist area[a]	2.51	1.08
16	We can have frequent contact[b]	2.37	1.00
17	The partner is known by my advisor[a]	2.01	1.07
18	The partner is known by someone from my network (e.g. relatives, friends)[a]	1.94	1.09

Scale ranging from 1 (not important) to 5 (very important).
[a] Statements about the characteristics of the partner.
[b] Statements about the characteristics of the partnership.

Statements relating to spatial and social accessibility to the partner and flexibility of the arrangement were also considered important. Minimising the costs of carrying out the transaction puts emphasis on the spatial aspects, i.e. aiming to make the distance travelled during hauling and spreading the shortest possible (e.g. Araji et al., 2001). The perception of closeness in terms of distance from the animal house to the fertilised fields of the partner farm seems to be more important to the exporters than the ease of access and field structure which is probably due to a generally high and uniform quality of infrastructure in Denmark. Social accessibility to partners can be viewed as ease of communication, as seen that the exporters considered statements like 'the partner is easy to get in touch with' important. The results also showed that exporters expect a good partner to be flexible in terms of timing and amount of manure received. This could also cover agreement on the nutrient content of the manure delivered. With strict manure regulation and requirements on N-utilisation in manure (e.g. 75% for pig slurry) the receiving farmer is very dependent on the correct nutrient content. It seems that the 'good' partner provide the correct values on nutrient content which is often based on independent laboratory control.

Prior knowledge of the partner was ranked as being of moderate importance (mean value < 3), indicating that exporters did not consider prior knowledge as crucial when finding a new partner, although 89% of them knew their existing partner before setting up their arrangements (Fig. 1). The low importance of information about the potential partner through embedded ties (e.g. farm advisors, relatives, friends) was also shown by the statements 'the partner is known by my advisor' and 'the partner is known by someone from my network' which ranked lowest of all statements. Statements regarding the importance of partner characteristics were ranked low, indicating on average that many farmers consider that a good partner does not necessarily need to run a professional farm, be knowledgeable about regulations or be a skilled farmer. Apparently their main concern was that 'the partner runs a solid business, so the arrangement can be extended', indicating that they are more interested in 'long-term' partnerships than specific characteristics of the partner. As for communication with the partner, timely, but not necessarily frequent communication was perceived as important by exporters as a way of minimising information costs. In more than 60% of the farmers' existing arrangements, exporters communicated with partners less than 5 times per year (Fig. 1), implying that many exporters consider frequent communication to be unnecessary as long as their partners are easy to get in touch with in a timely and direct way.

As Table 3 summarises, the statements related to the function of the partnership were generally considered more important than statements related to the characteristics of the partner – and for the latter, access to his/her fields and timely information was more important than knowledge or the partner and his/her professionalism. This makes sense in a transaction cost perspective, where information costs, negotiation costs and monitoring and enforcement costs are all minimised in partnerships, which are long-term, stable and flexible, while the formal character of the agreements, which are required by the legislation, secures that the prior knowledge of the partner are of less importance.

4.4. Variables influencing the perceptions of successful collaborative arrangements

In this section it was investigated if and to what extent variables related to the exporting farm and farmer, and to the experiences that he/she has obtained in existing partnerships influence his/her perceptions of what would be important when seeking a new partner and maintaining a functioning partnership.

Ten of the 18 statements were related to farmers' perceptions of partner characteristics. Factor analysis on these 10 statements using principal component extraction combined with a varimax rotation resulted in three factors with eigenvalue > 1. The KMO statistic for the data was 0.79, i.e. greater than the minimum level of 0.6 for this type of analysis. The three-factor solution gave the most interpretable factors and was judged to be most useful (Table 4). These factors explained 69% of the total variation, a satisfactory amount in social sciences (Hair et al., 2010).

The three partner factors were labelled '*spatial*', '*respect*' and '*social*', respectively. Factor 1 (*spatial*) had significant loads from spatial aspects regarding the distance to and accessibility to the fertilised fields on the partner farm. A wide collection of concerns regarding partner performance loaded significantly on factor 2 (*respect*). Factor 3 (*social*) included the importance of prior knowledge of the partner and information about the potential partner through social networks.

Eight statements were related to farmers' perceptions of the partnership characteristics. Factor analysis produced a number of components with an acceptable KMO statistic of 0.72, and which explained 71% of the variance within the statements (Table 5). A three-factor solution gave the most interpretable factors and was judged to be the most useful.

The first factor, '*flexibility*', includes the expectations that a partner is willing to make adaptations as to timing, amount and

Table 4
Varimax rotated factor loadings for characteristics of the partner.

	Factor			Communality
	1 Spatial	2 Respect	3 Social	
The partner is a person I already know	0.11	0.25	**0.79**	0.69
The partner is a person known by someone from my network (e.g. relatives, friends)	0.09	0.06	**0.80**	0.65
The partner is a person from the local area	0.27	0.06	**0.68**	0.54
The partner is known by my advisor	−0.02	0.31	**0.56**	0.41
The partner is a competent farmer in his/her specialist area	0.09	**0.86**	0.20	0.79
The partner is well informed about environmental regulations and subsidies	0.11	**0.83**	0.15	0.73
The partner runs a professional farming enterprise	0.10	**0.85**	0.17	0.75
Fields of partner are located close to my animal houses	**0.83**	0.03	0.19	0.72
Fields of partner are aggregated and not dispersed	**0.89**	0.16	0.10	0.82
Fields of partner are easy to access	**0.91**	0.09	0.07	0.84
Total variance explained (%)	24	24	22	
Cumulative variance explained (%)	24	48	69	

Extraction method: Principal component analysis.
Rotation method: Varimax rotation with Kaiser normalisation.
Factor loadings >|0.4| are in bold.

Table 5
Varimax rotated factor loadings for characteristics of the partnership.

	Factor			Communality
	1 Flexibility	2 Reliability	3 Communication	
The partner is easy to get in touch with	0.14	0.15	**0.83**	0.74
We can have frequent contact	0.21	0.03	**0.86**	0.79
The partner fulfils our agreements	0.06	**0.84**	−0.11	0.72
The partner runs a solid business, so the arrangement can be extended	0.11	**0.65**	**0.45**	0.63
The partner informs me well in advance of changes which may affect our agreement	0.05	**0.86**	0.19	0.78
The partner is flexible as to when he receives the manure	**0.80**	0.18	0.13	0.68
The partner is flexible in relation to the amount of manure	**0.77**	0.06	0.19	0.63
The partner is flexible and will accept manure outside the agreed period if I have a problem with storage capacity	**0.81**	−0.04	0.08	0.67
Total variance explained (%)	25	24	22	
Cumulative variance explained (%)	25	49	71	

Extraction method: Principal component analysis.
Rotation method: Varimax rotation with Kaiser normalisation.
Factor loadings >|0.4| are in bold.

emergency (no space for manure storage) of manure acceptance. The second factor, '*reliability*', had high loadings on shared goals, long-term partnership, and timely communication in relation to changes in the arrangement. The third factor, '*communication*', consisted of the accessibility to the partner and the frequency of making contact, as well as a cross-loading of 0.45 to timely communication.

In order to explain the influence of farm/farmer characteristics on the farmers' perceptions, six separate multiple regressions were performed, one for each set of factor scores from the PCA, as dependent variables. Regression on all variables resulted in the models summarised in Table 6. Previous studies using a similar approach (e.g. Flaten et al., 2005; Koesling et al., 2004) have reported fairly low goodness-of-fit numbers. The goodness-of-fit coefficients obtained in the present study were low, indicating that the variables used were either not very suitable in explaining the variation, or that farmers' perceptions of successful collaborative arrangements were very person-specific. As the respondents were a fairly homogeneous group of large-scale intensive livestock farmers, only relatively small variation in their perceptions on manure exporting partnerships could be expected. Regressions made on the factors, *reliability* and *flexibility* were not significant at $P < 0.05$. As shown in Table 3, the statements particularly related to *reliability* and *flexibility* factors were however highly ranked by manure exporters. This means that characteristics of farm/farmer and existing collaborative arrangement do not specifically influence the exporters'

Table 6
Results of multiple regressions for perceptions of farmers in selecting a partner and maintaining the partnership against farm/farmer characteristics and existing collaborative arrangement variables[a] ($n = 644$).

Independent variables	Selecting a partner			Maintaining the partnership		
	Spatial	Respect	Social	Flexibility	Reliability	Communication
Characteristics of farm/farmer (manure exporter)						
Age	−0.06	***0.19	***0.14	0.00	−0.05	***0.13
Agricultural education[b]	−0.12	−0.21	−0.26	−0.20	−0.09	*−0.39
Production type[c]	−0.05	−0.10	−0.05	0.00	$^{(*)}$0.15	**−0.23
Organic[d]	**−0.32	0.00	−0.06	−0.09	$^{(*)}$−0.22	0.11
Number of partners[e]	*0.10	**−0.13	−0.07	*0.11	0.03	−0.03
Annual labour input	0.01	0.06	*−0.09	0.01	−0.03	−0.03
Geography[f]	0.06	***0.47	0.02	$^{(*)}$0.16	0.02	***0.31
Characteristics of existing collaborative arrangement						
Prior knowledge of the partner[g]	**0.39	0.15	***0.42	−0.09	0.08	***0.47
Manure transportation and application by exporter[h]	***0.57	−0.10	0.02	−0.05	0.10	0.00
Transport distance[i]	***−0.37	$^{(*)}$0.15	$^{(*)}$−0.16	0.00	−0.02	−0.11
Communication frequency[j]	$^{(*)}$0.13	0.01	***0.28	0.04	$^{(*)}$0.15	*0.16
Sell manure[k]	−0.03	*0.21	0.06	*−0.20	0.02	0.13
Duration of partnership[l]	0.04	−0.11	−0.11	−0.05	0.06	−0.03
Adjusted R^2	***0.184	***0.105	***0.096	$^{(*)}$0.011	0.003	***0.098

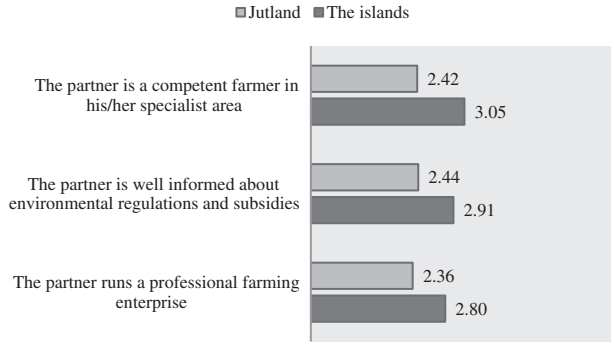
[a] Variables and models significant at $^{(*)}P < 0.10$, $^{*}P < 0.05$, $^{**}P < 0.01$ and $^{***}P < 0.001$.
[b] Measured as a dummy variable where 1 denotes agricultural education and 0 denotes otherwise.
[c] Measured as a dummy variable where 1 denotes dairy production and 0 denotes pig production.
[d] Measured as a dummy variable where 1 denotes organic farming and 0 denotes conventional farming.
[e] Number of manure receiver that each exporter had in 2012.
[f] Measured as a dummy variable where 1 denotes farms in the islands (Funen and Zealand) and 0 denotes farms in Jutland.
[g] Measured as a dummy variable where 1 denotes the exporter knew the partner before making the arrangement and 0 denotes otherwise.
[h] Measured as a dummy variable where 1 denotes the exporter took responsibility for both manure transportation and application and 0 denotes otherwise.
[i] Measured as a dummy variable where 1 denotes actual transportation distance was longer than 5 km and 0 denotes shorter than 5 km.
[j] Measured as a dummy variable where 1 denotes the exporter had frequent communication with the partner (from monthly to daily communication) and 0 denotes the exporter had communication with the partner only for practical purpose in manure distribution (maximum 5 times a year).
[k] Measured as a dummy variable where 1 denotes the exporter sold manure to the partner and 0 denotes the exporter provided manure for free.
[l] Measured as a dummy variable where 1 denotes the duration of partnerships was longer than 10 years and 0 denotes shorter than 10 years.

perceptions of importance on the *reliability* and *flexibility* of the partnerships, as these factors seem to be of high relevance for most of the exporters.

Regarding the *spatial* aspect of successful collaborative arrangements, organic farmers seemed to place less emphasis on the distance to, and accessibility of, their partner, whereas there was no significant difference between dairy and pig producers. A previous study showed that 92% of 98 organic dairy farmers surveyed supplied their manure to other organic (mainly crop) producers (Asai et al., Forthcoming), and organic dairy farms were the main providers of organic manure for specialist organic crop farms, especially in Jutland (Asai et al., 2012a). Thus, organic crop farms rely on obtaining manure from organic livestock producers, which may lead to the acceptance of longer transport distances than for conventional farms as organic farms cover only 7% of the farmed area and are thus much more dispersed than conventional farms (Asai, 2013). In the present study, spatial aspects were considered important by farmers with many partners. This could be farms in areas of shortage of land for manure export, where the distances to transport the manure could drive up the costs. The importance of this aspect is confirmed as farmers who carried the burden of transport and spreading in their existing partnership also found distance and accessibility to be highly important when selecting a new partner.

Respect for the partner owing to his/her professional skills and business expertise were more important for older farmers than for younger. Moreover, farmers with small numbers of partners tended to appreciate the importance of partner profile. Interestingly, farmers on the islands were significantly more concerned about the characteristics of partners, as is evident from the significant differences in mean values of each statement between Jutland and the islands (Fig. 2). There are two possible explanations to that. First, crop production dominates in the islands because of the fertile soils and thus the chances of manure exporters finding a suitable partner within the local community are high, leaving more room to critically assessing the potential partners. In contrast, the density of livestock production is quite high in Jutland and there is strong competition between exporters for access to fields, resulting in them having increasing numbers of partners and/or transporting manure long distances, and less room for being selective. Second, there are higher numbers of part-time and hobby farmers on the islands, and thus manure exporters could be more concerned about the profile of potential partners if they prefer to link up with a person running a stable business, hoping for a long-term partnership.

Social aspects, e.g. previous knowledge of the partner, were perceived as more important by older than by younger farmers when selecting a new partner. Previous experiences with close social relations in the partnerships also tended to affect the views on this aspect in relation to the establishment of new partnerships. On the other hand, the importance of social aspects appeared to be less important for larger businesses (represented as annual labour input). Previous experiences with larger transport distances also tend to downgrade the importance attributed to social aspects. These findings suggest that experienced farmers already in existing partnerships with good communicating and close by partners appreciate the social aspect, based on their prior experiences. In contrast younger farmers with large business units and who are dependent on long distance export are less concerned about the social aspects, as their primary aim is to comply with the regulations.



Scale ranged from 1 (not important) to 5 (very important)
Mean values of scales in the islands were significantly higher than in Jutland at P <0.001

Fig. 2. Mean values of statements regarding aspects related to *respect* as perceived by farmers in Jutland and the islands.

Concerning the function of the partnership, both farmers with more partners and those in the islands where livestock density is low were particularly concerned about *flexibility* (e.g. being more flexible to the amount and timing of manure reception). Other analyses showed that farms with a higher livestock density (expressed in the amount of nitrogen in manure per hectare before exporting) tend to connect with more partners (Asai, 2013), probably due to a surplus of manure. Judging from this result, very intensive livestock producers seem to be particularly in the need of having flexible receivers as the distribution of manure is challenging especially in areas with a high livestock density (Jacobsen, 2011). *Flexibility* can also be a factor in demand in areas with low livestock density, e.g. to deselect farmers with less potential for receiving excess manure. This is however somewhat speculative, based on the present study. Farmers who were able to put a price to the manure were likely to be less concerned about *flexibility*, which makes sense, as manure exchange in a situation of sufficient demand to produce an economic return would not be expected to create problems of getting rid of the manure.

Communication, such as ease of making contact and frequent and timely communication, is essential in collaborative arrangements, as greater sharing of information between partners reduces uncertainties and thus avoids critical situations, resulting in lower transaction costs. In the present analysis, the importance of *communication* was rated higher by farmers with long experience of farming, without agricultural education, and with close social relations with partners. In addition, same as for *respect* and *flexibility*, farmers in the islands perceived that communication was highly important to keep the collaborative arrangement functioning well. Although Denmark has adopted country-wide designations of NVZ, our findings showed that regional variations in environmental and socio-economic conditions were partly reflected in differences in exporters' perceptions of successful collaborative arrangements, but further studies would be needed to make firm conclusions on the explanations for these results.

4.5. Future research addressing manure importers' perceptions

Previous studies investigating the willingness of crop producers to accept animal manure have found several barriers to manure exchange (Battel, 2006; Núñez and McCann, 2004). For instance, Battel (2006) found that farmers in Michigan, USA, were concerned about manure containing weed seeds, spreading equipment causing soil compaction and manure application interfering with the timeliness of springtime field activities. In a survey of farmers in Missouri and Iowa, Núñez and McCann (2004) found that factors such as transportation costs and smell significantly affected crop farmers' acceptance of manure. In a Danish context, smell is also an important issue and so it has been found that farmers prefer to receive degassed manure from biogas plants as opposed to raw slurry. Another option is to make agreements with exporting farmers not to apply manure before weekends or important events, etc. It is likely that the 'good' partner observes these requirements as the receiving farmer does not want to have a 'bad' standing in

the local community. These and the findings of the present study should help farm advisors begin to identify barriers that prevent farmers from entering into collaborative arrangements for manure exchange.

Although the excessive amount of manure produced has been an environmental issue in Denmark, 19% of farms registered in the Danish Fertilizer Account, solely applied mineral fertiliser in 2009 (Asai et al., 2012b). These farmers could include those who had the possibility to accept manure from neighbour livestock farms, but instead, had chosen to use only mineral fertiliser. Future research addressing these potential manure importers' perceptions will find the barriers to facilitate the collaboration between livestock and crop producers. Results from the future study will complement the present findings and provide a fuller picture for e.g. local farm advisors.

5. Conclusions

Danish farmers have developed their own strategies to respond to environmental regulations of manure application. Self-governing manure exchanges have been widely undertaken by farms in local communities, so that large-scale, intensive livestock farms can achieve the required balance between amount of manure produced and available land for manure application. Despite the potential for improved efficiency of manure use, few studies have examined livestock farmers' perceptions of coordinated arrangements with recipient farms and factors in successful arrangements. According to our analyses on surveyed data, the farmers' perceptions of successful collaborative arrangements were especially related to the reliability of the partner for fulfilling the agreements and for up-keeping a stable and long term partnership, but also to the physical and social accessibility to partners, and the flexibility of the arrangement. Although existing collaborative arrangements are largely policy-driven, the majority of manure exporters surveyed considered stable trustworthy relationships with local partners to be of significant importance. This trust covers a range of issues including price, time of delivery, machinery used etc. These are novel empirical insights into how livestock farmers view their reliance on partners for successful manure exchange in order to comply with environmental regulations.

Collaborative arrangements for manure exchange are currently coordinated under various institutional arrangements between manure exporters and importers, so analysing farmers' perceptions of successful collaborative arrangements and identifying specific factors which are underlying these perceptions are both complex and challenging. However, it was confirmed that perceptions differ according to age of farmer and the scale and type of the business he/she runs, but also that previous experiences with partnerships are influential when seeking new partners. The geography of the farm location also had significant influence on the farmers' views on the successful partnership, yet the present study does not allow concluding on explanations for this. The findings may be relevant for intensive livestock production areas in other European countries where area-wide integration of livestock and crop production through farm partnerships can improve nutrient management, and thus lower the environmental impacts at landscape scale.

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