Livestock farmers' attitude towards manure separation technology as future strategy

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Abstract

In this paper, an ordered probit model is used to assess the factors that affect the probability of livestock farmers having plans to adopt manure separation technology in the future. A survey, based on a postal and computerized questionnaire of representative dairy and pig farms in the Netherlands was carried out in 2009. The results show that age of farmer and a variable which accounts for the interaction between size and location of the farm are important variables explaining the probability of farmers having plans to adopt manure separation technology. Furthermore, farmers who agreed that future application norms are the driving force for considering adoption of manure separation technology were more likely to consider manure separation as the right strategy for their farm. This outcome implies that farmers are considering manure separation as a strategy to survive the more stringent future application norms. Policy implications are that young farmers with bigger Dutch size unit located in manure regions where there is oversupply of manure are more likely to adopt manure separation technology in the future.

Key words: Manure separation, livestock farms, ordered probit model

1. Introduction

Manure from livestock production, when recycled to agricultural land, supply plant nutrients and organic matter that can help to meet crop requirements and maintain soil fertility (Smith et al., 2000). The environmental concerns and impacts of livestock production systems, however have been the actual concerns of many countries, especially countries or regions with a dense animal population (Jongbloed and Lenis, 1998). Intensive livestock production is connected with a number of environmental impacts, which can be divided into three categories: (i) concerns related to the soil (accumulation of nutrients), (ii) the water (eutrophication), and (iii) the air (Heij and Erisman, 1995, van den Brandt and Smit, 1998, Jongbloed and Lenis, 1998). Hence, the increase in the number of animals brings new management challenges in manure handling and utilization (Alocilja, 1998). Since 1985 the Dutch government has implemented several laws and regulations to prevent the growth of livestock production and to reduce and control manure production and use. The Netherlands was the first country to initiate a large research program to reduce the environmental impact of livestock production (Jongbloed and Lenis, 1998). Different strategies such as reduction of mineral input via alteration of feed and treatment of manure on a large scale for export purposes were proposed (Jongbloed and Lenis, 1992; Jongbloed and Henkens, 1996).

Vast literature exists on the potential contribution of manure separation technologies to handling and utilization of livestock manure (Melse and Timmerman 2009, Burton 2007, Melse and Verdoes 2005, Moller et. al, 2000, Burton 1997). Melse and Verdoes (2005) carried out a study on four farm-scale systems for treatment of liquid manure to promote the introduction of manure treatment in the Netherlands by giving research support to farmer initiatives in this field. A study by Burton (2007) provides a review of the scope of separation technologies and concludes that manure separation improves handling of manure and results in a reduced environmental impact. It is therefore, established from previous studies that manure separation technologies are considered essential for sustainable livestock operations in areas with a high livestock density as they result in better utilization of manure and reduced environmental impact.

Technology adoption and diffusion have been a major part of the agricultural research agenda of economists and sociologists for several decades (Feder et al., 1985; Nowak 1987; Feder and Umali, 1993). It has generally been found that the use of new agricultural technologies is a function of farm and farmer characteristics and specific features of the particular technology (Feder et. al., 1985). De Souza Filho et al. (1999) carried out a study to analyze the determinants of farmers' decisions on whether or not to adopt low-external-input and sustainable agriculture technology by applying a dynamic econometric framework. Oude Lansink et al. (2003) carried out a survey of pig farmers to identify the factors that affect the probability of farmers having plans in implementing different strategies such as build a barn or set up a manure processing facility at the own farm by applying a multivariate probit model. With respect to manure separation technologies in Netherlands, in spite of the ongoing research on technical and economic aspects of manure separation and the recognition that manure separation will contribute to handling of livestock manure, many techniques that were developed never made it to successful long-term application (Melse and Timmerman, 2009). There have been no studies identifying the link between knowledge and attitudes of livestock farmers towards manure separation technologies. Sustainability of agricultural production depends largely on actions of farmers and their ability to make decisions given the level of knowledge and information available to them (Rahman, 2003). This study aims to identify the factors that affect the probability of livestock farmers having plans to adopt manure separation technologies in the future. Econometric model using ordered probit is used to estimate the "strategy to adopt" probability. Of particular interest to policymakers is the role that farm characteristics (size, location, soil type etc) among other factors, play in the adoption process and thereby indentify farms that are most likely to adopt treatment technologies. Moreover, results will enable us to assess the effect that a change in an explanatory variable has on the probability of adoption.

The paper is organized as follows: the next section presents an overview of manure separation in Netherlands followed by the section outlining the econometric model used. Next we discuss the dataset and the variables used in the analysis. After presenting the results, the final section presents conclusions.

2. Manure separation

One of the major attractive futures of manure separation is its ability to concentrate manure solids which will reduce the volume and expense of transportation. The purpose of separation is to achieve a manure fraction with a higher manurial value and a limited volume, which is more saleable than the raw manure and which can compete with chemical fertilizer. A simple manure separation results in two fractions: a liquid fraction with a low dry matter and solid fraction. Phosphate is accumulated in the solid fraction as the phosphate is present in the manure in solid form which can be transported to long distances while, the liquids could be applied on own farm or near the manure source as nitrogen fertilizer.Various manure separation technologies are commercially available and the amounts of dry matter and nutrients included in the solid fraction are dependent on the technology used (Moller et al., 2007a). A selection of different technologies is illustrated by Moller et al. (2000).

In the Netherlands manure treatment has been taking place since the 1970's (Melse and Timmerman, 2009) when measures were introduced to limit the loss of minerals into the environment. The most commonly used separation techniques are based on simple technological solutions where solids are mechanically separated from liquid, e.g. by screw pressing, centrifugation, filtration or sieving (Burton, 2007). The total cost of separation process varies widely depending on the sophistication and efficiency of the technique utilized (Moller et. al, 2000). Sedimentation, mechanical screen separation and centrifugation are simple techniques that are cost effective, while biological treatments, evaporation, ultrafiltration and reverse osmosis are complex and expensive techniques (Burton, 1997). The driving forces for manure treatment initiatives in the Netherlands, according to Melse and Timmerman, 2009, are summarized as; the introduction of stringent nutrient legislation on land application of minerals, high off farm disposal cost of untreated manure and farm expansion whereby farmers get a discount of 50% on manure production right for extending their farm if all manure is processed to products sold outside Dutch agriculture.

3. Model specification

The dependent variable used in this study was the respondents' score on the statement "manure separation is the right strategy for my farm". Since the dependent variable (strategy to adopt) takes more than two values and these values have a logical ordering, an ordered probit model which is estimated using maximum likelihood method (Maddala, 1983, p46) was used to evaluate the factors that influenced the strategy to adopt probability. The dependent variable determines whether or not the livestock farmers perceive manure separation as a strategy for manure management in the future.

Following Maddala (1983) and Verbeek (2004) ordered probit model is based on latent (unobserved) response variable y_i^* which can be defined as a function of observed variables, x_i, representing technology attributes and farm and farmer specific characteristics, and unobserved variables, ε_i as follows:

$$y_i^* = \beta' x_i + \varepsilon_i \quad (1)$$

The relationship between the observed variables, y and the latent variable y_i^* is given by:

$$\begin{aligned} y_i &= 1 \quad if \ y_i^* \le \gamma_1, \\ y_i &= 2 \quad if \ \gamma_1 < y_i^* \le \gamma_2, \\ y_i &= 3 \quad if \ y_i^* > \gamma_2, \end{aligned} \quad (2)$$

Where γ's are cut off points to be estimated jointly with β' which is a vector of coefficients. In this formulation, the $\beta' x_i$ is an index function such that higher values for this index correspond with, on average, larger values for y_i. For example, a positive (negative) β implies that the corresponding variable increases (reduces) farmer's willingness (strategy) to adopt manure separation technology. The ε, a vector of error terms, is normally distributed $N[0,\sigma^2]$.

The implied probabilities that the ordered dependent variable y takes the different values can now be given by:

$$\begin{aligned} P(y_i = 1|x_i) &= P(y_i^* \le \gamma_1|x_i) = P(\beta' x_i + \varepsilon_i \le \gamma_1) = \Phi(\gamma_1 - \beta' x_i) \\ P(y_i = 2|x_i) &= \Phi(\gamma_2 - \beta' x_i) - \Phi(\gamma_1 - \beta' x_i) \\ P(y_i = 3|x_i) &= P(y_i^* > \gamma_2|x_i) = 1 - \Phi(\gamma_2 - \beta' x_i)_{2} \end{aligned} \quad (3)$$

where Φ is the cumulative probability function of a standard normal distribution.

The marginal effects of the explanatory variables, X_i on the probabilities are not equal to the coefficients. For the binary explanatory variables, the marginal effect is the difference in probabilities between setting the explanatory variable to 1 and to 0, setting the other explanatory variables at their sample means. While the marginal effect of continuous variables is the change in the probabilities of the different outcomes with a change in one of the explanatory variables. The marginal probabilities could therefore be calculated by evaluating the density functions at the relevant points and multiplying by the associated coefficient from the ordered probit model as:

$$\frac{dprob\ (y_i)}{dx_i} = \left[\Phi(\gamma_{i-1} - \beta^{'} x_i) - \Phi(\gamma_i - \beta' x_i)\right]\beta \tag{4}$$

4. Data description

A survey, based on a postal and computerized questionnaire using the software Select Survey, of representative dairy (n=350) and pig farms (n=39) in the Netherlands was designed to elucidate livestock farmers' knowledge of and attitude towards manure separation technology as a livestock waste management option. The sample for the survey consisted of farms which are part of the Dutch Farm Accountancy Data Network (FADN). For the survey contingency 7 point likert-scale and open questions have been applied. The study is based on cross section data collected in the year 2009. In general, dairy farmers were more responsive (48%) than pig farmers (33%). In this study, we only consider dairy farms as the response rate of pig farmers was low. In addition to the questionnaire, data from FADN were also used. Data pertaining to age of farmer, size of farm and location of farm were taken from FADN while data pertaining to knowledge and attitude information were elicited from the questionnaire.

Definitions and descriptive statistics of the variables used in the analysis are shown in Table 1. Farm plans depend on farmer characteristics and farm characteristics (Oude Lansink et al. 2003). Variables *Age*, *DSU*, *Mover*, *Mshort*, and *Milkint* were amongst the explanatory variables used in the empirical model. In most adoption studies, age of farmer and size of the farm are widely believed to influence the plan or decision to adopt. It is assumed that the younger the farmer, the more likely he/she will adopt (Rogers, 1995). Moreover, the larger the farm the more likely that the farmer will adopt. The average age of the farmer in the survey was 50 and average size of farms expressed in Dutch size unit (DSU) is 111.50. Farm size was calculated as the weighted total number of dairy cows with weights for each cow being 1.2 (LEI, 2009). In addition to DSU, milk intensity expressed as milk production per ha of land is included. To account for any potential regional differences, three manure regions are distinguished, namely *undersupply* where demand for manure exceeds supply, *neutral* means there is no over nor under supply of manure and *oversupply* means supply of manure exceeds demand. The regions are expressed by two dummy variables, *Mover* and *Mshor*t. The summary statistics in table 1 indicate that 28% of the farms are located in manure region where there is oversupply of manure and 24% where there is under supply of manure. In this analysis, it is hypothesized that farms located in a region where there is *oversupply* of manure will be more likely to adopt manure separation technology.

Variables such as knowledge of and attitude towards manure separation were included in the model. Respondents were asked to give a score to a statement based on a likert scale with 1 strongly disagree to 7 strongly agree (table 1). The focus of the study is on the role that knowledge and attitude of farmers play in influencing the likelihood of adoption in the future. A variable measuring knowledge about manure separation (technical, cost and composition) was included. Variables pertaining to farmers' perception on the different attributes of manure separation, such as the ability to use N and P optimally, the attractiveness of the thin and thick fractions, the low cost of manure separation, its environmental friendliness and solution for stringent future application norms were included. Respondents were also asked if manure separation is the right strategy for their farm.

Table 1 Description, mean and standard deviation of the variables used

Variable	Description	Mean	SD
General information			
Age	Age of the farmer in years	50.15	9.86
DSU	Dutch size unit	111.50	66.62
Mover	Manure region (1 if manure region is oversupply region)	0.28	0.45
Mshort	Manure region (1 if manure region is undersupply region)	0.24	0.43
Milkint	Milk intensity (1000 kg/ha)	14.84	6.87
Knowledge and attitude information			
Knowms	Likert scale of knowledge[1] of manure separation (1 to 7)	2.36	1.29
NPopt	Likert scale of response (1-7) to the statement that "Through manure separation N and P can be used optimally"	4.11	1.63
Thickf	Likert scale of response (1-7) to the statement that "Thick fraction is economically attractive"	3.56	1.53
Thinf	Likert scale of response (1-7) to the statement that "Thin fraction is economically attractive"	3.37	1.48
Lowcost	Likert scale of response (1-7) to the statement that "The relatively low cost of manure separation is a reason for me to consider manure separation "	3.14	1.56
Norms	Likert scale of response (1-7) to the statement that "Future application norms are the reason for me to consider manure separation"	3.15	1.61
Envt	Likert scale of response (1-7) to the statement that "I will start with manure separation because it is good for the environment"	2.73	1.42
Dependent variable			
MSstrg	Manure separation is the right alternative(strategy) for my farm (0=disagree, 1=neutral, 2= agree)	0.61	0.69

[1]Knowledge means technical knowledge, cost and composition

5. Results

The results of the ordered probit model estimation are presented in Table 2. Examining the results of the farmer and farm characteristics revealed that, *age* of farmer is significant at 5% critical level with a negative effect on the attitude of farmers in considering manure separation as the right strategy for their farm. A negative coefficient in age which was in line with our expectation indicates that the probability of manure separation as the right strategy decreases with an increase in age, suggesting that young farmers are more likely to consider manure separation technology as the right strategy for their farm. The sign of the parameter *DSU* is counter-intuitive but not statistically significant. We hypothesized that the larger the farm the more likely that the farmer will consider manure separation technology as a strategy to reduce the volume and transportation of manure. The regions dummy variables, *Mshort* and *Mover*, are also insignificant throughout the model. It is however, important to consider the location of the farm and its size. To account for the interaction between location and size of the farm, a new variable was created namely, *Sizereg*. The parameter for *Sizereg* is significant at 10% critical level with a positive effect on the strategy to adopt suggesting that large farms located in regions with higher supply of manure are more likely to adopt manure separation technology.

Table 2 Parameter estimates of ordered probit model

Variable	Coefficient	Z statistics	P>/Z/
Age	-0.029**	-2.04	0.042
Mover	-0.866	-1.23	0.219
Mshort	-0.437	-1.28	0.202
DSU	-0.003	-1.27	0.205
Thickf	0.078	0.65	0.518
Envt	0.291**	2.54	0.011
Norms	0.721**	5.20	0.000
NPopt	0.184*	1.61	0.107
Lowcost	0.549**	3.86	0.000
Sizereg	0.011*	1.91	0.056
Cut1	4.102**		
Cut2	6.838**		
Number of observations	140		
Log likelihood	-60.00		
LR χ^2	151.10		
Prob> χ^2	0.000		
Pseudo R^2	0.5574		

*significant at 10% critical level

**significant at 5% critical level

Model results pertaining to knowledge about and attitude towards manure separation revealed that the following parameters have a positive and significant effect (at 5% critical level) on the strategy to adopt: belief that manure separation is good for the environment (*Envt*), future application norms are the reason for considering manure separation strategy (*Norms*), low cost of manure separation (*Lowcost*). The belief that through manure separation NPK minerals can be used optimally is weakly significant at 10% critical level.

Cut1 and Cut2 in table 2 are the estimated cut-off points. In our ordered probit model, there are two cut-off points to distinguish three groups (0,1,2). In order to assess whether three different attitude levels can be distinguished, we can check whether the two cut-off points are significantly different from each other. Looking at the 95% confidence bound of Cut1 [1.91-6.29] and of Cut2 [4.40-9.27] shows that the mean value of Cut1 (4.10) is outside the 95% confidence interval for Cut2 and vise versa, suggesting that both cut-off points are significantly different.

The Likelihood Ratio Chi-Square test in table 2 provides a test for the hypothesis that all predictors' regression coefficients in the model are simultaneously equal to zero. The p-value from the LR test, 0.000 leads us to reject the null hypothesis and that at least one of the regression coefficients in the model is not equal to zero.

The goodness of fit of the ordered probit model is assessed using McFadden's R^2 which is given by: $McFadden\, R^2 = 1 - \log L_1 / LogL_0$ where log L_0 is the maximum value of the loglikelihood function when all parameters, except the intercept, are set to zero and log L_1 is the maximum value of the loglikelihood of the model without constraints. The McFadden R^2 as shown in table 2 is 0.5574 indicating that the model's predictive power is good. An alternative way to evaluate the predictive power of the model, count R^2, is calculated by comparing the actual and predicted outcomes (see table 3). The benefit of the cross-tabulation of actual and predicted outcomes is to compute the percentage of correct predictions based on the model versus naive predictions based on a model with an intercept term only. The predictions for farmer's attitude towards manure separation as the right strategy are correct in 83% of cases (i.e. 65+42+9= 116). A correct prediction is when the model guesses 0 and it actually was, and likewise when it predicts 1 when the decision was 1. If one were to make a naive prediction, the correct prediction rate would be the largest category, that is 0 (71) and the correct prediction rate would be 51%. Therefore, the model gives good increase in correct predictions (32%) compared to naïve prediction.

Table 3 Cross-tabulation of actual and predicted outcomes

Actual MSstrategy*	Predicted probability MSstrategy			Total
	Disagree (0)	Neutral (1)	Agree (2)	
Disagree (0)	65	6	0	71
Neutral (1)	6	42	4	52
Agree (2)	0	8	9	17
Total	71	56	13	140

*Response to the question "Manure separation is the right alternative(strategy) for my farm".

The marginal effects of all independent variables are presented in Table 4. The marginal effects indicate, for example, that if age increases by one unit, the probability of considering manure separation as the right strategy goes down. The marginal effects also illustrate that a higher score in the perception that manure separation is good for the environment increases the likelihood of considering manure separation as the right strategy.

Table 4 Marginal effects of the ordered probit model on the probability of manure separation as the right strategy

Variable	Marginal effects		
	Prob (disagree)	Prob (neutral)	Prob (agree)
Age	0.0117	-0.0115	-0.0002
Mover	0.3208	-0.3164	-0.0043
Mshort	0.1687	-0.1664	-0.0023
DSU	0.0012	-0.0011	-0.0002
Sizereg	-0.0046	0.0045	0.0008
Thickf	-0.0309	0.0304	0.0005
Envt	-0.1157	0.1137	0.0020
Norms	-0.286	0.2810	0.0050
NPopt	-0.0730	0.0718	0.0013
Lowcost	-0.2177	0.2139	0.0038

6. Conclusion

Technologies for manure separation are well researched and ready for use in practice. Their use however have been limited in the Netherlands. The purpose of this study was to determine the role that farm and farmer characteristics, knowledge and attitude of farmers play in influencing the likelihood of adoption in the future. Econometric model using ordered probit is used to estimate the "strategy to adopt" probability.

Results show that *age* of farmer had a significant and negative effect on the attitude of farmers in considering manure separation as the right strategy for their farm, indicating that young farmers are more likely to consider manure separation technology as the right strategy. None of the other farm characteristics, size of the farm and region, were significant in the model. When the interaction between size of the farm and region were accounted for, the parameter was significant with a positive effect on the strategy to adopt suggesting that large farms located in regions with higher supply of manure are more likely to adopt manure separation technology. Farmers who agreed that manure separation was good for the environment were more likely to consider manure separation as the right strategy for their farm. Moreover, farmers who agreed that the cost of setting up manure separation is low were more likely to adopt while the belief that through separation, NPK could be optimally used was weakly significant. Another driving force in influencing the attitudes of farmers towards manure separation is the introduction of more stringent mineral legislation on land application of minerals. Results show that farmers who agreed that future application norms are the driving force for considering adoption of manure separation technology were more likely to consider manure separation as the right strategy for their farm. This outcome implies that farmers are considering manure separation as a way forward to survive the more stringent future application norms. This result is in accordance with a study on manure separation in Netherlands (Melse and Timmerman 2009) which concluded that the introduction of stringent nutrient legislation was one of the driving forces for manure separation initiatives in the Netherlands.

The results of this study contribute to identifying the link between knowledge and attitudes of livestock farmers towards manure separation technologies by developing an appropriate ordered probit model. Results will enable us to assess the effect that a change in explanatory variables, such as age of farmer, location and size of farm has on the probability of adoption in the future. Policy implications are that young farmers with bigger Dutch size unit located in manure regions where there is oversupply of manure are more likely to adopt manure separation technology in the future. This will enable policy makers to identify and target the farmers that will most likely adopt the technology in the future. Moreover, the results of this study are useful for the technology developers and distributers or innovative entrepreneurs in giving insights into what determines decision making behavior of farmers and thereby, target those farmers which are most likely to adopt.

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