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Farm size and farmers environmental-friendly practices in livestock farming

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(preliminary, please do not quote)

Abstract
Agriculture is among the major contributors to climate change, accounting for 24 percent of global CO_2 emissions. Within the agricultural sector, livestock has a major role in greenhouse gas emissions. However, animal husbandry also affects the environment through nitrogen leaching to water tables from manure and slurry spread or stored on the soil. Both impacts can be diminished by appropriate practices, concerning the effluents storage and the modalities of their spreading on the soil. We investigate to what extent farmers adopt such practices and, more importantly, which are farm and farmers' characteristics more conducive to the adoption of such practices. In particular, given the predominance of small farms in Italian agriculture, we assess the effect of farm size on the adoption of appropriate practices. To this purpose, we estimate ordered and binomial probit models of the adoption of virtuous practices from data of the 2010 Agricultural Census in Piedmont (Italy). The results suggest that, in general, larger farms are more likely to adopt virtuous practices, but the effect of farm size is nevertheless rather weak. Technical and cost issues linked to the physical conditions (location in hills and mountains) are apparently a relevant impediment to these practices.

1. Introduction

Agriculture is among the major contributors to climate change. According to IPCC (2007) agriculture accounts for 24 percent of global CO_2 emissions, though in developed countries this figure is less, amounting to 9 percent in the USA in 2015 (US EPA, 2017) and to 9.8 percent for the EU-28 (Eurostat, 2017). Within the agricultural sector, livestock is widely recognized as a major cause of environmental pollution (FAO, 2013) mainly due to the increased amount of manure produced by animals per unit of utilized agricultural area. Two topics of major importance are surface and groundwater nitrate contamination because of runoff and soil leaching, and atmospheric impacts from ammonia and greenhouse gas emissions (Capri et al., 2009; Solazzo et al., 2016). These causes of environmental impact derive primarily from production, storage and agronomic utilization of animal manure. The correct management of these phases reduce emissions to soil, water and air. For this reason European (e.g. 91/676/EEC and 2010/75/EU Directives), national (e.g. codes of good agricultural practices) or regional regulations regulate housing systems, manure storage and land spreading, stimulating the adoption of correct techniques for the reduction of emissions from manure. Several scientific papers (Sommer and Hutchings, 2001; Amon et al., 2006; Dinuccio et al., 2008; Webb et al., 2010) or official documents, such as the Best Available Techniques reference document (European Commission, 2015) describe the main findings, the principal techniques adoptable and their associate reduction levels of the emissions.

It is therefore important to investigate to what extent farmers adopt such practices and, more importantly, which are farm and farmers' characteristics more conducive to the adoption of such practices. This could help in designing and fine-tuning policies addressed to a larger adoption of environmentally friendly practices. In particular, there is a discussion in the political field on whether large or small farms are more environmentally friendly. Supporters of small and local farms argue that "industrial agriculture" is the main responsible for the environmental impact, while supporters of large farms claim that small farms have not enough technical skills nor the possibility to invest in more environmentally friendly techniques.

The goal of this paper is therefore to explore the issue by examining the distribution of these practices among farmers and to assess farm and farmers' characteristics that favour the adoption of environmentally friendly practices. To this purpose, we use data of a specific region, Piedmont, and exploit the records of the 2010 Agricultural Census, to estimate the effect of different farmer and farm characteristics on the adoption of environmentally friendly practices. Based on these data, for the Piedmontese cattle sector, production (milk or beef), housing systems (tied stall or pen), kind of manure (solid or liquid), storage facilities (in field, on pad or tank uncovered or covered) and spreading systems (on soil without incorporation, with soil incorporation and in bands, injection or fertigation) will be taken into account to correlate the more environmental friendly practices to the farm and farmers' characteristics.

2. Theoretical model and econometric strategy

For a theoretical approach, we refer to the popular farm household models (Nakajima, 1986; Singh et al., 1986; Huffmann, 1991), also as adapted to environmental supply (Vanslembrouck, 2002; Dupraz et al., 2003). We keep into consideration the possibility that the farmer is concerned with the environment, so that he/she maximizes his/her utility having in its arguments income Y and environmental quality A:

$$\text{Max } U = U(Y, A)$$

$$\text{S.t.:} \quad Y = p_q q(x, z) - p_x x - p_z z \qquad (1)$$

$$A = A(z)$$

$$z \geq 0$$

where: q is the product; p_q its price; x the inputs (labour included) and p_x their price; z are inputs devoted to environmental protection and p_z their price. Notice that the production function allows an effect of the environmental input on production that can be either positive or negative (depending on $\partial q/\partial z$ being greater or smaller than 0).

The first order condition concerning z is:

$$\lambda_1 [p_q \, \partial q/\partial z - p_z] + \lambda_2 \cdot \partial A/\partial z + \lambda_3 = 0 \qquad (2)$$

where λ_1 and λ_2 are the Lagrange multiplier representing the marginal utility of income and environmental quality, respectively, and λ_3 is the multiplier of the positivity constraint on z.

Condition (2) can be written:

$$p_q \, \partial q/\partial z + \lambda_2/\lambda_1 \cdot \partial A/\partial z = p_z - \lambda_3/\lambda_1 \qquad (3)$$

The first term on the RHS represents the marginal contribution of the environmental input to the production. The second term indicates the economic value of the utility generated by the marginal change of the input. If the positivity constraint is met, and λ_3 is zero, then z will be used up to the point when its price is compensated for by the benefits in terms of income and utility from the environmental quality. If the first term on the RHS is negative, and the second one is positive, but does not sufficiently offset it, then all the RHS is negative and the environmental input is not used. Otherwise, a negative first term reduces the positive effect of the second one; if both are positive, their effect adds on, and the use of the environmental input is greater.

For the empirical exercise, the environmental input is represented by a set of environmental practices farmers can adopt, that are detailed in the Data section. In our empirical analysis, they can take either the form of discrete adoption of progressively more environmentally friendly practices, or of individual practices.

3. Data

The data for this study are drawn from the 2010 Agricultural Census of Piedmont, of which we could access the individual farm records. Piedmont is an administrative Region in the North-West of Italy, near the French border. Though traditionally an industrial area, it has a strong agriculture, producing both commodities and specialties (in particular, wine). Animal husbandry is important, especially in the plains, both devoted to dairy and beef.

We specifically address the behaviour of bovine animal farms, both beef and dairy. Hence, from the 65,448 farms recorded in the Census we selected 12,752 farms with bovines[1]. There is a large variation in herd size, with a large concentration as to the number of farms in small sizes, and a small number of big farms, with a maximum of 6,129 heads. The average size is 61 heads, and the median is 24.

The Agricultural Census surveyed several aspects of animal effluents management. In particular, farmers were asked about the storage modalities of animal effluents generated within the farm. Non-mutually exclusive modalities for manure were recorded as dichotomous indicators of: in field heaps; uncovered pad; covered pad. The highest frequencies were "uncovered pad alone" (6,982 farms) and "field heaps only" (3,507), but there was a variety of multiple choices. Considering that open-air storage favours gas emissions, and that in field storage is prone to soil leaching, we created an ordinal variable (LEV_MAN) as a proxy for careful environmental management of manure with the following levels: 2 for covered pad only; 1 for uncovered pad alone or in association with covered pad or field heaps; 0 for field heaps only or no response (assuming in this case the worst practice).

For slurry, the modalities were: covered tank; uncovered tank; covered lagoon; uncovered lagoon. In this case, the dominant form is covered tank alone (2,179 farms) or in association with uncovered tank (74). Considering that from the environmental impact point of view the discrimination is whether the storage is covered or uncovered, we created a dichotomous variable (LEV_SLR) equal to 1 if the modalities were covered lagoon only or covered tank alone or covered tank in association with covered lagoon, and otherwise equal to 0.

Table 1 shows the distribution of farms and animals according to the levels of these two variables.

[1] These farms are those who responded a positive number to the question of the Census asking the average number of dairy cows (or buffalo) or other bovine and buffalo animals that were in the farm, after dropping missing observations on the other variables of interest.

A second group of practices with environmental implications are the modalities of manure and slurry spreading. As to this issue, the Census records the area treated with animal effluents with different modalities: spreading of solid manure, of which the area on which manure was quickly (within 4 hours) incorporated into the soil; spreading of slurry, of which the one where it was quickly incorporated, the one where it was incorporated within 24 hours, the one in band spreading or shallow injection or fertigation. We considered whether to use the share of treated over total area as the dependent variable, but we concluded that this is not advisable since there may be several limitations on the area that can be spread (vicinity to water streams, slopes, etc.), and we therefore used dichotomous variables of the different practices. Since there is not much overlapping among them, we analyzed each practice separately. The distribution of farms and animals according to these different practices are shown in Table 2.

The explanatory variables comprise farm and farmer's characteristics. Farm economic size is represented by the Standard Output (SO)[2]. We also considered the herd size i.e., the number of bovine heads (inclusive, in the few cases when this applied, of buffalos). This is because we included in our sample all farms having livestock, regardless of the number of heads. Therefore, a farm can be large in economic terms even when livestock is a small part of its global turnover. Location of the farm in mountains or hills (as compared to the plains, taken as reference) were other variables, since slopes can pose problems in storage and spreading. Organic farming is an indicator of environmental attitudes or orientation, while the presence of computers, the use of Internet, and having a farm website were introduced as candidate proxies for the technical and market skills of the operators (all these are dichotomous variables). Finally, classical personal characteristics were considered: age, gender, education (number of years of regular schooling), attendance to agricultural studies. In general, higher education levels are a priori expected to favour the adoption of a more modern and environmentally-friendly management of animal effluents, but this is an empirical issue. Younger farmers are also a priori expected to be more ready to adopt the environmentally-friendly practices, both because presumably more sensitive to environmental issues and because of the longer time horizon to exploit the benefits of the related investments. No a priori expectation can be done concerning farmer's gender. Table 3 shows the descriptive statistics of the variables.

4. Results

A first group of results concerns the manure storage. The largest group of farms (57.5 percent of the total number) belongs to the intermediate level of environmental friendly practices, and only 6.5 percent to the best one.

Table 4 presents the results of different specifications of ordered probit models, as estimated on the whole sample. The models differ as to the variables chosen to represent farm size. One specification introduces the Standard Output and its square (to account for a curvilinear effect), while keeping the herd size as a further control. The other specification keeps herd size and its square, and uses SO as a further control. Though SO and herd size are correlated ($r = 0.62$) a likelihood ratio test rejects the exclusion of either in both models[3]. The results suggest that the probability of belonging to the most virtuous group increases with farm size (both measured in terms of Standard Output and in terms of herd size) though at a decreasing pace (the squared term). The effect of size is nevertheless

[2] The Standard Output of an agricultural product (crop or livestock) is the average monetary value of the agricultural output at farm-gate price, in euro per hectare or per head of livestock, as used in the Farm Accounting Data Network of the European Union. SO coefficients are established at area levels (Eurostat, 2018). The farm SO is the sum of SO coefficients multiplied by the relevant hectares or heads of livestock.

[3] In some following models, the LR tests could not reject the exclusion, so we dropped the relevant variable.

rather weak, since the estimated marginal effects (at the mean values of the variables) indicate that an increase of 100,000 euro of SO increases the probability of belonging to the "best" group by 0.94 percent only, and that an increase of 100 heads in herd size translates into an increase of the same probability by 3 percent. Under the assumption of the curvilinear relationship implied by the model, the probability of a higher environmental level increases to a maximum of 1,505,000 euro of SO, or to 1,261 heads, and then declines.

Among farm characteristics, organic farming has a positive effect, though rather weak again (+1.9% for the best category). Location in the mountains has the strongest negative effect, since it decreases the probability to belong to the "best" category by around 5 percent and increases the probability of belonging to the "worst" category by 21 percent. This effect is undoubtedly due to the greater difficulty, and hence higher costs, of building manure storage plants on the slopes. The effect of using a computer and having a website are opposite (positive and negative, respectively), but again of limited impact. While using the computer is an indicator of managing skills, having a website is probably linked to small, marginal animal farms, possibly practising direct sales. These farms are often less technologically advanced, and hence less used to environmentally-friendly practices. As to operator's characteristics, the "environmental quality" is higher for younger, male, and more educated farmers. Every additional year of age decreases the probability to belong to the "best" category by 0.06 percent, while a male operator is 1.6-1.7 percent more likely to be in the "best" group. The effect on this probability of each additional education year is only 0.1 percent, while an education in the agricultural field has no statistically significant effect. The effects of age and education are as predicted, but it is difficult to explain the effect of gender.

As to slurry management, only 17.2 percent of the livestock farms adopt covered tanks only, which has a lower environmental impact. Results of the probit models (Table 5) suggest that in this case too farm economic size or herd number have a positive effect on the probability of adopting the less impacting practice. Again, the effect is rather weak, as 100 more heads increase the probability by only 4.1 percent, and 100,000 euro of additional SO increase the probability by 4.1 percent. The maximum probabilities of belonging to the "best" group are in this case at 702,000 euro of SO and at 792 heads.

Unlike for manure, organic is not significant, like computer use and the presence of a website. Location of the farm in hills or mountains has a significant and negative effect on the probability of adoption of covered tank: the relevant marginal effect is 4.4 to 4.6% for hills and 10.3 to 10.6% for mountains. Younger and male operators are again significantly more likely to adopt the more environmentally friendly practice (the marginal effect is -0.13-0.14 percent for every year of age, and -1.7-2.1 percent for a female operator). The effect of education is in this case unexpectedly negative, and an additional year of education decreases the probability by 0.4 percent, at the mean values of the variables.

A second question can be raised, namely whether the nature of livestock (dairy vs beef) can be a determinant of the environmental practices. As noted before, we had the information about the average number of dairy cows, and of other bovines, that were present in the farm. We then classified the farms as dairy when this was the only or the prevailing (in terms of number of animals) form. According to this criterion, there were 6,101 dairy farms (47.8%) and 6,651 "other" (52.2%), that included 45.3% and 54.7% of the total number of animals, respectively. It should be noted, nevertheless, that the division is not necessarily between dairy and beef farms, since while an item is "dairy cows", the other comprises all other animals, including, e.g., replacing animals or livestock producing calves for fattening farms.

There are nevertheless two ways in which the nature of the livestock can influence the environmental practices. One possibility is that it raises the probability of the virtuous practices, but that the other determinants (e.g., farm size, education, etc.) have the same effect regardless of the nature of the livestock. This possibility can be represented by models in which the nature of the livestock is represented by a dummy variable. A second possibility is that the nature of the livestock influences the way the other variables affect farmers' choice, so that actually there are two different behavioural models. Formally, calling y_i the dependent variable, d a dummy variable equal to 1 if the farm is a dairy one, else 0, X all other independent variables, and e_i the random term, the "dummy model" can be represented as:

$$y_i = aX_i + bd_i + e_i \qquad \text{("dummy model")} \qquad (4)$$

while the "split model" is:

$$y_i = a_0 X_i + e_i \qquad \text{if } d=0$$

$$y_i = a_1 X_i + e_i \qquad \text{if } d=1$$

$$\text{or:} \qquad y_i = a_0 X_i(1-d) + a_1 X_i d + e_i \qquad \text{("split model")} \qquad (5)$$

A statistical test can be used to identify the best model, since the "split model" nests the "dummy model". The restriction to be tested is $a_0 = a_1$ (except for the constant term). We estimated the relevant models and run likelihood ratio tests. The tests strongly rejected the restriction, both for manure and for slurry storage. Hence, we can conclude that the farmers' behavior is different depending on their being dairy or beef farmers.

Table 6 presents the results of the models of manure storage estimated separately. Though the statistical test rejects the constraint of equal parameters, there are not very strong differences between the separate models. The effect of farm size is larger for dairy farms than for "other" farms, if measured in terms of herd size, while the opposite holds in terms of SO. The effect also runs out later for SO (the maximum probability is 1.6 million Euro of SO for dairy farms, as compared to 0.547 for "Others"), while the opposite holds true for herd size (404 for dairy farms vs 1,032 for "other" farms). This is probably due to the different orientation of beef farms. The small ones usually rear local breeds with a suckling cow orientation. The large ones import calves and fatten them on a large scale, and they are more equipped for appropriately dealing with effluent storage. Organic has a significant positive effect for dairy farms, but it is negative or not significant for the "other" farms. An explanation for this counterintuitive result might be that several small and marginal beef farms joined the EU scheme for organic agriculture that provided subsidies to farmers that adopted the relevant rules. These farmers were probably less skilled and less careful about the technical possibilities to reduce the environmental impact. An alternative explanation is that organic dairy farms could produce manure and no slurry whereas both the groups (organic and non-organic) of the "other" farms always produce manure that requires similar management practices. Like for the other indicators, farm location in the mountains has a negative significant effect in both groups, as well as operator's age and female gender. Education has a significant and positive effect only for "other animals".

Table 7 reports the results of the probit models of slurry storage estimated separately. They are relatively similar to the ones of manure management. The effect of farm size (both in terms of SO and in terms of herd size) are only slightly larger for dairy farms. The maximum probability is reached at 724 heads for dairy farms vs 825 for "other" farms, while for SO the relevant data are 0.733 and 0.687 million Euro, respectively. Organic is only significant for dairy farms, while hills, mountains, operator's age have the usual negative impact. Gender is significant and negative for "other" farms but not for dairy farms, and education is significant, and negative, for dairy farms only.

About 87 percent of the farmers spread manure on the fields, but only 13.2 percent incorporate it quickly, a more environmentally-friendly practice. While 26 percent of farmers spread slurry, only 797 (6.3%) incorporate it within 24 hours, and even less (279, 2.2%) incorporate it quickly or spread it in bands or as a fertigation (145, 1.1%).

The results of the estimated separate probit models for manure spreading are presented in Table 8 and those of slurry spreading in Table 9.

Larger farms are less likely to spread solid manure (this is the conventional practice), but are more likely to do so incorporating it immediately, which helps increasing soil organic carbon and to reduce odour and gaseous emissions. Again, the effects of farm size, both negative and positive, are quite modest. A 100,000-euro increase in SO (or a 100 heads increase in herd size) translates into a 0.18 percent (0.2 percent) increase in the probability of quick manure incorporation. The impact of location in mountains or hills is negative but weak for hills (about 2 percent), more substantial for mountains (13 percent).

As to slurry spreading (Table 9), the probit analysis suggests that a larger farm size makes slurry spreading more likely. Only for one model of band spreading the estimates of farm size are not significant, a result probably due to the tiny percentage. In any case, the effects of farm size on all types of practices are again small, since the impacts of a 100,000 increase of SO or of 100 heads are always modest (under 1 percent, except for slurry spreading, for which it is 1.6 percent).

Location in the mountains or hills is less conducive to all types of slurry spreading. Its effect is substantial for slurry spreading in general (-14.5% for hills, -16% for mountains), and appreciable for slurry incorporation within 24 hours (-5% and -6%, respectively), while it is negligible for quick incorporation (-1.6% and -2%) and not significant for band spreading (-0.15% and -0.2%), probably due to the small numbers. Age is only significant for the model of generic slurry spreading and for slurry incorporation within 24 hours and bears the usual negative sign, meaning that younger operators are more likely to adopt these practices. Education and operator's female gender bear in most cases a negative sign, but the effects are negligible to all practical respects.

An analysis similar to the previous one concerning the nature of the animals was performed for the spreading practices. Again, the statistical tests reject the restriction of equal parameters, so that it must be concluded that the behavior is different for dairy farms and for "other" farms.

A lower percentage of dairy farms (85.2%) than "other" farms (89.2%) spread manure, but there are not substantial differences in the determinants of this choice. In this case (Table 10), farm size (as measured by SO, but not as herd size) is less conducive to manure spreading. Location in hills lowers the probability of spreading manure for dairy farms, while organic production increases it. No variable except farm size affects the choice for the "other" farms.

As to the practice of manure spreading with quick incorporation (table 11), the effect of farm size is positive with a peak at 0.539 million SO (or 500 heads) for dairy farms, and higher ones (0.669 million SO or 619 heads) for "other animals". However, the marginal effects are weak. The other negative effects are for hills or mountains, with no substantially different patterns for either group.

Spreading slurry is a less popular practice, concerning 23.6% of dairy farms and 28.2% of "other" farms. The effect of farm size is positive (Table 12), with peaks at 0.750 million SO or 1702 heads for dairy farms, and at 0.869 million SO or 736 heads for "other animals". Location in the mountains decreases the probability by around 14 percent for dairy farms and by 16 percent for "other animals", while the respective data for hills are 11-12 percent and 16-15 percent. The effect of age is negative but weak as usual (around -0.2 percent for each additional year) and quite homogeneous across the two groups. Gender is only significant and negative for “other” farms. The negative impact of education is weaker for dairy farms (-0.6 percent for each additional year) than for “other” (0.8 percent).

Spreading the slurry and incorporating it into the soil within 24 hours is practiced by 5.2 percent of dairy farms, and by 7.2 percent of the “others”. This practice too is favored by farm size (Table 13), up to 0.613 million SO or 942 heads for dairy farms, and 0.977 million SO or 377 heads for the “other animals”. The negative effect of location in hills and mountains is found here too, but to a lesser extent. Location in hills decreases the probability by around 4 percent for dairy farms and by 2 percent for “other animals”, while for mountains the respective estimates are 5 and 2 percent. Female gender is significant and negative for dairy farms only, but it is negligible in practical terms.

Few farmers spread slurry and incorporate it quickly. They are 1.8 percent among dairy farms, and 2.6 percent among the “other animals” farms. The probit model (Table 14) suggests a weak evidence of a positive effect of farm size, especially for “other” farms[4]. As in the other cases, the magnitude of the effect is very low. Hills and mountains show a negative effect on the probability of adoption of this practice, but a weak one (around 1-2 percent at the mean values of the variables).

The number of farmers spreading the slurry and incorporating it in bands, injection or fertigation is tiny, since they are 0.8 percent of the dairy farms and 1.4 percent of the “other animals” farms. It is therefore not surprising that the model, though overall statistically significant, gives no sound suggestion as to the relevant variables (Table 15). The effect of farm size is significant in one model, and the negative impact of location in hills is only significant in two models.

5. Summary and conclusions

In this paper, we tried to ascertain the degree of diffusion among farmers of practices for storing and spreading animal effluents suggested to reduce the environmental impact. We were interested in assessing which, if any, farm and farmers’ characteristics are more favourable to such practices. Of particular interest was the relationship between farm size and the adoption of environmentally friendly practices, given the widespread criticism against “industrial” animal production. To this purpose, we estimated different ordered or binomial probit models of the determinants of environmentally friendly practices from data of the 2010 Agricultural Census of Piedmont (Italy).

The overall picture emerging from these preliminary results is not clear-cut. To be fair, there is no evidence that smaller farms are more environmentally virtuous. To the contrary, the results suggest that larger farms (both in terms of farm turnover and in terms of herd size) are more likely to adopt more sustainable practices. However, the effect of farm size is, in all cases considered, rather weak. Substantial increases in farm size are needed to raise by modest percentages the likelihood of adoption. Apparently, farm or herd size counts, but does not make a substantial difference in the probability of adopting environmentally friendly practices. It is quite possible that the main reason behind the positive effect of farm size is economies of scale. This is especially likely in case of manure and slurry storage, since the costs for building pads and tanks are less than proportional to their volume. In the case of spreading techniques, some of those more environmentally friendly require specialised machinery that, again, has lower average costs on larger quantities.

[4] Due to lack of variation in the split sample, two variables (Organic and Internet) were dropped from this model. For the same reason, Organic and Web were dropped from the model of slurry band spreading (Table 15).

That costs linked to the technical feasibility of plants are at the origin of the differences in behaviour is also suggested by the other almost constantly found (negative) determinant of adoption, i.e., farm location in hills or mountains, as the impact in terms of lower adoption probability is in most cases substantial. Animal farms in these areas are generally smaller than the general average, but this characteristic should be controlled by the relevant explanatory variable. Hence, it is more to the higher costs of building storage plants, and to spread animal effluents, in these situations, that an explanation can point.

The other farmers' and farm characteristics do not have generalised effects. Some virtuous practices are more adopted by younger and educated farmers, but this does not apply to all. A puzzling result, for which we do not have an interpretation, is the negative effect of female operators. More generally, much of the variation is arguably due to idiosyncratic characteristics of farms and farmers.

If the above considerations are correct, the policy implications of our results are that, if the adoption of these practices is desirable, the public effort should be directed to overcome the major difficulties, linked to the technical costs of plants and machinery. Hence, subsidies in this direction should be modulated favouring small farms and farms in unfavourable physical conditions.

A final critical consideration concerns the way we assessed the effect of farm or herd size. The models we employed assume a continuous effect of farm size on the probability of adoption of environmentally-friendly practices. It is quite possible, though, that there are some discontinuities in the effect of farm size, due, e.g., to some threshold in the dimension of the storage plants. In this case, the behavioural model should be different for farms above and below the threshold. We made some experiments in this direction, by splitting the sample at given farm sizes and testing the split models vs the pooled one. The tests generally rejected the pooled sample model, suggesting that there are actually differences in the behaviour of small and large farms. However, the identification of which threshold divides "small" and "large" farm behaviour, and whether the threshold is an indicator of some technical and economic discontinuity, are still unresolved issues on which we are still working.

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Table 1 - Distribution of farms and animals by impact level of manure and slurry storage

LEV_MAN	N. farms	%	N. animals	%	LEV_SLR	N. farms	%	N. animals	%
0	4,583	35.9	155,461	19.7	0	10,564	82.8	608,559	77.1
1	7,335	57.5	579,589	73.4	1	2,188	17.2	181,000	22.9
2	834	6.5	54,509	6.9					
	12,752	100.0	789,559	100.0		12752	100.0	789,559	100.0

Table 2. Distribution of farms and animals by practices of manure and slurry spreading

		N°	%
Manure spreading, of which:	Farms	11,135	87.3
	Animals	660,573	83.7
Manure quick incorporation	Farms	1,682	13.2
	Animals	131,518	16.7
Slurry spreading, of which:	Farms	3,313	26.0
	Animals	288,872	36.6
Slurry incorporated within 24 hrs	Farms	797	6.3
	Animals	89,379	11.3
Slurry quickly incorporated	Farms	279	2.2
	Animals	30,138	3.8
Slurry band spreading	Farms	145	1.1
	Animals	12,091	1.5

Table 3. Descriptive statistics of the variables

	Mean	Std.Dev.
Standard Output (Meuro)	0.09	0.22
N. bovine heads	61.92	135.24
Organic (0-1)	0.03	0.17
Computer (0-1)	0.11	0.32
Web (0-1)	0.03	0.16
Internet (0-1)	0.02	0.13
Hills (0-1)	0.35	0.48
Mountains (0-1)	0.23	0.42
Operator's age (yrs)	52.55	13.62
Gender (1=F)	0.21	0.40
Education (years)	7.87	2.80
Agricultural education (0-1)	0.05	0.21

Tab. 4. Results of the ordered probit of manure storage

	Model 1					Model 2				
			Marginal effects					Marginal effects		
	Coeff.	t-ratio	Y=0	Y=1	Y=2	Coeff.	t-ratio	Y=0	Y=1	Y=2
Constant	0.643***	8.165				0.577***	7.283			
Standard Output (Meuro)	0.829***	6.060	-0.309	0.214	0.094	-0.105	-1.485	0.039	-0.027	-0.012
St. Output squared	-0.275***	-8.890	0.103	-0.071	-0.031					
N. bovine heads	0.001***	4.430	0.000	0.000	0.000	0.002***	14.398	-0.001	0.001	0.000
N. bovine heads squared						-0.000***	-11.296	0.000	0.000	0.000
Organic (0-1)	0.148**	2.400	-0.053	0.023	0.019	0.148**	2.410	-0.054	0.035	0.019
Computer (0-1)	0.091**	2.408	-0.033	0.023	0.011	0.066*	1.744	-0.024	0.017	0.008
Web (0-1)	-0.142**	-1.970	0.054	-0.039	-0.015	-0.126*	-1.758	0.048	-0.035	-0.013
Internet (0-1)	-0.051	-0.587	0.019	-0.014	-0.006	-0.040	-0.465	0.015	-0.011	-0.004
Hills (0-1)	0.011	0.472	-0.004	0.003	0.001	0.038	1.549	-0.014	0.010	0.004
Mountains (0-1)	-0.546***	-18.656	0.210	-0.161	-0.050	-0.523***	-17.744	0.201	-0.153	-0.048
Operator's age (yrs)	-0.006***	-5.984	0.002	-0.001	-0.001	-0.005***	-5.491	0.002	-0.001	-0.001
Gender (1=F)	-0.165***	-6.135	0.063	-0.045	-0.017	-0.154***	-5.714	0.058	-0.042	-0.016
Education (years)	0.008*	1.730	-0.003	0.002	0.001	0.010**	2.030	-0.004	0.003	0.001
Agricultural education (0-1)	-0.049	-0.886	0.019	-0.013	-0.005	-0.048	-0.860	0.018	-0.013	-0.005
Threshold	1.956***	100.451				1.963***	100.375			
N. Observations	12,752					12,752				
Log-Likelihood	-10,504.09					-10,469.48				
Chi-sq (d.f.)	1,033.66	(13)				1,102.87	(13)			
McFadden Pseudo R-sq.	0.047					0.050				

Note: ***, **, * = significant at the 1, 5, 10% level

Tab. 5. Results of the probit of slurry storage

	Model 1			Model 2		
	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.
Constant	-0.484***	-4.697		-0.450***	-4.394	
Standard Output (Meuro)	1.726***	8.463	0.412			
St. Output squared	-1.230***	-5.756	-0.294			
N. bovine heads				0.002***	7.937	0.000
N. bovine heads squared				-0.000***	-5.298	-0.000
Organic (0-1)	0.119	1.496	0.030	0.133*	1.668	0.035
Computer (0-1)	-0.061	-1.309	-0.014	-0.060	-1.290	-0.014
Web (0-1)	-0.029	-0.323	-0.007	0.005	0.050	0.001
Internet (0-1)	0.055	0.511	0.013	0.056	0.521	0.014
Hills (0-1)	-0.199***	-6.577	-0.046	-0.186***	-6.086	-0.044
Mountains (0-1)	-0.49***	-12.543	-0.103	-0.495***	-12.423	-0.106
Operator's age (yrs)	-0.006***	-4.628	-0.001	-0.006***	-4.865	-0.001
Gender (1=F)	-0.075**	-2.051	-0.017	-0.086**	-2.370	-0.021
Education (years)	-0.015**	-2.341	-0.004	-0.014**	-2.127	-0.003
Agricultural education (0-1)	-0.029	-0.413	-0.004	-0.018	-0.253	-0.004
N. Observations	12,752			12,752		
Log-Likelihood	-5,647.65			-5,656.780		
Chi-sq (d.f.)	395.322	(12)		377.070	(12)	
McFadden Pseudo R-sq.	0.034			0.032		

Note: ***, **, * = significant at the 1, 5, 10% level

Tab. 6. Results of the ordered probit of manure storage, separately by nature of the livestock (model 1)

Model 1

	Dairy farms					Other				
			Marginal effects					Marginal effects		
	Coeff.	t-ratio	Y=0	Y=1	Y=2	Coeff.	t-ratio	Y=0	Y=1	Y=2
Constant	0.692***	6.089				0.438***	3.930			
Standard Output (Meuro)	1.041***	4.669	-0.400	0.292	0.108	1.791***	7.600	-0.658	0.462	0.196
St. Output squared	-0.324***	-6.542	0.125	-0.091	-0.034	-1.636***	-9.820	0.601	-0.422	-0.179
N. bovine heads	0.000**	2.047	0.000	0.000	0.000	0.001***	5.531	0.000	0.000	0.000
N. bovine heads squared										
Organic (0-1)	0.291***	3.406	-0.107	0.069	0.037	-0.011***	-0.118	0.004	-0.003	-0.001
Computer (0-1)	0.077	1.393	-0.029	0.021	0.008	0.063	1.200	-0.023	0.016	0.007
Web (0-1)	-0.096	-0.957	0.037	-0.028	-0.009	-0.157	-1.520	0.059	-0.044	-0.015
Internet (0-1)	-0.111	-0.847	0.043	-0.033	-0.011	-0.045	-0.391	0.017	-0.012	-0.005
Hills (0-1)	-0.031	-0.844	0.012	-0.009	-0.003	0.067*	2.097	-0.025	0.017	0.008
Mountains (0-1)	-0.544***	-13.435	0.212	-0.164	-0.048	-0.488***	-10.917	0.187	-0.146	-0.041
Operator's age (yrs)	-0.007***	-5.322	0.003	-0.002	-0.001	-0.003***	-2.458	0.001	-0.001	0.000
Gender (1=F)	-0.079***	-2.065	0.031	-0.023	-0.008	-0.213***	-5.575	0.080	-0.059	-0.021
Education (years)	0.003	0.369	-0.001	0.001	0.000	0.016**	2.252	-0.006	0.004	0.002
Agricultural education (0-1)	-0.088	-1.025	0.034	-0.026	-0.009	-0.046	-0.625	0.017	-0.012	-0.005
Threshold	1.918***	66.733				2.013***	74.905			
N. Observations	6,101					6,651				
Log-Likelihood	-5,011.655					-5,436.256				
Chi-sq (d.f.)	511.579	(13)				566.104	(13)			
McFadden Pseudo R-sq.	0.049					0.049				

Note: ***, **, * = significant at the 1, 5, 10% level

Tab. 6 (cnd). Results of the ordered probit of manure storage, separately by nature of the livestock (model 2)

Model 2

	Dairy farms					Other				
			Marginal effects					Marginal effects		
	Coeff.	t-ratio	Y=0	Y=1	Y=2	Coeff.	t-ratio	Y=0	Y=1	Y=2
Constant	0.472***	4.050				0.468***	4.208			
Standard Output (Meuro)	0.322*	1.872	-0.124	0.093	0.032	-0.126	-1.526	0.045	-0.0298	-0.0153
St. Output squared										
N. bovine heads	0.004***	10.547	-0.002	0.001	0.000	0.003***	11.952	-0.001	0.001	0.000
N. bovine heads squared	-0.000***	-8.521	0.000	0.000	0.000	-0.000***	-8.917	0.000	0.000	0.000
Organic (0-1)	0.256**	2.980	-0.095	0.064	0.031	0.006	0.073	-0.002	0.002	0.001
Computer (0-1)	0.025	0.440	-0.009	0.007	0.003	0.065	1.252	-0.023	0.015	0.008
Web (0-1)	-0.119	-1.176	0.046	-0.036	-0.011	-0.096	-0.929	0.035	-0.024	-0.011
Internet (0-1)	-0.075	-0.567	0.029	-0.022	-0.007	-0.048	-0.416	0.017	-0.012	-0.006
Hills (0-1)	0.030	0.797	-0.012	0.009	0.003	0.087***	2.686	-0.031	0.020	0.011
Mountains (0-1)	-0.472***	-11.424	0.184	-0.144	-0.040	-0.489***	-10.949	0.185	-0.139	-0.046
Operator's age (yrs)	-0.006***	-4.192	0.002	-0.002	-0.001	-0.003***	-2.619	0.001	-0.001	0.000
Gender (1=F)	-0.035	-0.901	0.014	-0.010	-0.003	-0.224***	-5.903	0.083	-0.058	-0.025
Education (years)	0.004	0.569	-0.002	0.001	0.000	0.017**	2.450	-0.006	0.004	0.002
Agricultural education (0-1)	-0.119	-1.384	0.046	-0.036	-0.011	-0.035	-0.472	0.013	-0.009	-0.004
Threshold	1.936***	66.721				2.008***	74.960			
N. Observations	6,101					6,651				
Log-Likelihood	-4,974.814					-5,436.440				
Chi-sq (d.f.)	585.262	(13)				565.735	(13)			
McFadden Pseudo R-sq.	0.056					0.049				

Note: ***, **, * = significant at the 1, 5, 10% level

Tab.7. Results of the probit of slurry storage, separately by nature of the livestock

	Model 1						Model 2					
	Dairy farms			Other			Dairy farms			Other		
	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.
Constant	-0.417***	-2.782		-0.565***	-3.967		-0.366**	-2.459		-0.553***	-3.894	
Standard Output (Meuro)	1.873***	6.44	0.454	1.597***	5.532	0.375						
St. Output squared	-1.277***	-4.163	-0.31	-1.163***	-3.872	-0.273						
N. bovine heads							0.002***	5.659	0.000	0.002***	5.627	0.000
N. bovine heads squared							-0.000***	-3.538	-0.000	-0.000***	-3.976	-0.000
Organic (0-1)	0.207*	1.894	0.055	0.01	0.089	0.002	0.212*	1.948	0.035	0.032	0.272	0.008
Computer (0-1)	-0.055	-0.811	-0.013	-0.07	-1.1	-0.016	-0.058	-0.848	-0.015	-0.07	-1.094	-0.017
Web (0-1)	-0.044	-0.344	-0.01	-0.008	-0.065	-0.002	-0.016	-0.124	0	0.028	0.222	0.007
Internet (0-1)	0.037	0.222	0.009	0.053	0.378	0.013	0.048	0.292	0.015	0.052	0.368	0.013
Hills (0-1)	-0.158***	-3.452	-0.037	-0.235***	-5.803	-0.054	-0.152***	-3.284	-0.045	-0.217***	-5.312	-0.052
Mountains (0-1)	-0.507***	-9.434	-0.111	-0.506***	-8.109	-0.099	-0.505***	-9.369	-0.108	-0.504***	-8.067	-0.103
Operator's age (yrs)	-0.006***	-3.292	-0.001	-0.005***	-3.118	-0.001	-0.006***	-3.548	-0.001	-0.005***	-3.155	-0.001
Gender (1=F)	0.01	0.198	0.002	-0.162***	-3.119	-0.036	-0.002	-0.032	-0.021	-0.172***	-3.326	-0.04
Education (years)	-0.025***	-2.659	-0.006	-0.005	-0.547	-0.001	-0.024**	-2.538	-0.003	-0.003	-0.361	-0.001
Agricultural education (0-1)	-0.146	-1.303	-0.033	0.04	0.439	0.01	-0.133	-1.184	-0.004	0.049	0.537	0.012
N. Observations	6,101			6,651			6,101			6,651		
Log-Likelihood	-2,684.51			-2,953.57			-2,690.95			-2,956.09		
Chi-sq (d.f.)	212.155	(12)		202.276	(12)		199.275	(12)		197.239	(12)	
McFadden Pseudo R-sq.	0.038			0.033			0.036			0.032		

Note: ***, **, * = significant at the 1, 5, 10% level

Tab. 8. Results of the probit of manure spreading

	Manure spreading						Manure spreading with quick incorporation					
	Model 1			Model 2			Model 1			Model 2		
	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.
Constant	1.392***	13.352		1.368	12.954		-1.142***	-10.276		-1.137***	-10.232	
Standard Output (Meuro)	-0.476***	-3.475	-0.098	-0.366***	-3.428	-0.075	0.965***	3.753	0.184	-0.009	-0.106	
St. Output squared	0.022	1.582	0.004				-0.748***	-3.312	-0.143			
N. bovine heads	0.000	-0.010	-0.000	0.000	0.205	0.000	0.000	0.528	0.012	0.001***	4.449	0.000
N. bovine heads squared				0.000	-0.633	-0.000				-0.000***	-3.165	-0.000
Organic (0-1)	0.240***	2.622	0.043	0.237***	2.594	0.043	0.055	0.586	0.019	0.062	0.661	0.013
Computer (0-1)	-0.049	-0.985	-0.010	-0.060	-1.193	-0.013	0.051	1.023	0.010	0.052	1.059	0.010
Web (0-1)	0.033	0.349	0.007	0.032	0.336	0.006	0.027	0.276	0.005	0.049	0.511	0.010
Internet (0-1)	-0.254***	-2.380	-0.060	-0.254**	-2.376	-0.060	-0.224*	-1.777	-0.037	-0.223*	-1.772	-0.038
Hills (0-1)	-0.176***	-5.364	-0.037	-0.172***	-5.222	-0.037	-0.106***	-3.366	-0.020	-0.096***	-3.024	-0.018
Mountains (0-1)	-0.065	-1.638	-0.014	-0.059	-1.467	-0.012	-0.893***	-17.032	-0.127	-0.889***	-16.929	-0.130
Operator's age (yrs)	-0.001	-0.625	0.000	-0.001	-0.481	0.000	0.002*	1.806	0.000	0.002*	1.754	0.000
Gender (1=F)	0.044	1.205	0.009	0.050	1.349	0.010	-0.004	-0.089	-0.001	-0.009	-0.221	-0.002
Education (years)	-0.012*	-1.775	-0.002	-0.012*	-1.741	-0.002	-0.002	-0.284	0.000	-0.001	-0.138	0.000
Agricultural education (0-1)	0.059	0.787	0.012	0.055	0.738	0.011	0.088	1.190	0.018	0.093	1.270	0.019
N. Observations	12,752			12,752			12,752			12,752		
Log-Likelihood	-4,803.829			-4,804.346			-4,725.559			-4,727.012		
Chi-sq (d.f.)	90.623	(13)		89.589	(13)		495.042	(13)		492.136	(13)	
McFadden Pseudo R-sq.	0.009			0.009			0.050			0.049		

Note: ***, **, * = significant at the 1, 5, 10% level

Tab.9. Results of the probit of slurry spreading

	Slurry spreading						Slurry spreading with quick incorporation					
	Model 1			Model 2			Model 1			Model 2		
	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.
Constant	0.155*	1.661		0.095	1.019		-1.825***	-9.454		-1.922***	-9.723	
Standard Output (Meuro)	0.519***	3.431	0.164	-0.069	-0.829	-0.022	1.086***	2.837	0.040	0.038	0.405	0.001
St. Output squared	-0.174***	-5.008	-0.055				-0.60**	-2.042	-0.022			
N. bovine heads	0.000***	3.065	0.000	0.002***	9.202	0.001	0.000	0.265	. 0.000	0.002***	4.101	0.000
N. bovine heads squared				-0.000***	-7.396	-0.000				-0.000***	-2.744	-0.000
Organic (0-1)	-0.117	-1.488	-0.035	-0.114	-1.459	-0.035	-0.239	-1.026	-0.007	-0.198	-0.867	-0.006
Computer (0-1)	0.116***	2.726	0.038	0.094**	2.181	0.030	0.108	1.373	0.004	0.101	1.290	0.004
Web (0-1)	-0.001	-0.008	0.000	0.013	0.151	0.004	0.035	0.220	0.001	0.048	0.298	0.003
Internet (0-1)	-0.263**	-2.496	-0.075	-0.260**	-2.461	-0.075	-0.127	-0.614	-0.004	-0.102	-0.496	-0.003
Hills (0-1)	-0.486***	-17.169	-0.145	-0.468***	-16.414	-0.140	-0.485***	-7.693	-0.016	-0.457***	-7.157	-0.015
Mountains (0-1)	-0.584***	-16.766	-0.163	-0.564***	-16.114	-0.158	-0.882***	-7.746	-0.021	-0.853***	-7.456	-0.021
Operator's age (yrs)	-0.008***	-6.984	-0.002	-0.007***	-6.586	-0.002	-0.002	-1.033	-0.000	-0.002	-0.710	-0.000
Gender (1=F)	-0.124***	-3.778	-0.038	-0.112***	-3.405	-0.035	-0.011	-0.147	0.000	0.001	0.011	0.000
Education (years)	-0.022***	-3.752	-0.007	-0.022***	-3.582	-0.007	0.009	0.773	0.000	0.011	0.933	0.000
Agricultural education (0-1)	0.044	0.681	0.014	0.042	0.652	0.014	-0.109	-0.855	-0.004	-0.111	-0.867	-0.004
N. Observations	12,752			12,752			12,752			12,752		
Log-Likelihood	-6,903.281			-6,884.645			-1,240.260			-1,236.385		
Chi-sq (d.f.)	803.407	(13)		840.679	(13)		204.137	(13)		211.886	(13)	
McFadden Pseudo R-sq.	0.055			0.058			0.076			0.079		

Note: ***, **, * = significant at the 1, 5, 10% level

Tab. 9 (cnd). Results of the probit of slurry spreading

	Slurry spreading with incorporation within 24 hrs						Slurry band spreading					
	Model 1			Model 2			Model 1			Model 2		
	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.
Constant	-1.071***	-7.441		-1.106***	-7.664		-2.371***	-9.728		-2.351***	-9.577	
Standard Output (Meuro)	1.102***	3.863	0.094	-0.023	-0.227	-0.002	0.955**	2.305	0.025	0.111	1.172	0.003
St. Output squared	-0.884***	-3.924	-0.076				-0.248	-1.006	-0.007			
N. bovine heads	0.001***	2.630	0.000	0.002***	7.179	0.000	0.000	-1.181	-0.000	0.001	0.985	0.000
N. bovine heads squared				-0.000***	-4.714	-0.000				0.000	-0.793	-0.000
Organic (0-1)	-0.196	-1.218	-0.014	-0.187	-1.165	-0.014	-0.491	-1.493	-0.008	-0.475	-1.446	-0.008
Computer (0-1)	0.098*	1.679	0.009	0.088	1.509	0.008	0.290***	2.919	0.010	0.305***	3.077	0.011
Web (0-1)	-0.145	-1.127	-0.011	-0.123	-0.950	-0.010	-0.667*	-1.911	-0.009	-0.659*	-1.890	-0.009
Internet (0-1)	-0.216	-1.345	-0.015	-0.229	-1.412	-0.016	0.064	0.257	0.002	0.078	0.318	0.002
Hills (0-1)	-0.633***	-14.161	-0.048	-0.614***	-13.642	-0.047	-0.062	-0.819	-0.002	-0.059	-0.773	-0.002
Mountains (0-1)	-1.102***	-13.618	-0.062	-1.090***	-13.410	-0.063	0.031	0.349	0.001	0.029	0.325	0.001
Operator's age (yrs)	-0.004**	-2.335	0.000	-0.004**	-2.191	0.000	0.002	0.816	0.000	0.002	0.770	0.000
Gender (1=F)	-0.158***	-2.715	-0.012	-0.149**	-2.570	-0.012	-0.250**	-2.512	-0.006	-0.264***	-2.640	-0.006
Education (years)	-0.007	-0.767	-0.001	-0.006	-0.604	0.000	-0.007	-0.449	0.000	-0.006	-0.404	0.000
Agricultural education (0-1)	0.058	0.639	0.005	0.056	0.620	0.005	-0.165	-0.878	-0.004	-0.160	-0.850	-0.004
N. Observations	12,752			12,752			12,752			12,752		
Log-Likelihood	-2,643.961			-2,637.844			-772.581			-774.909		
Chi-sq (d.f.)	674.700	(13)		686.934	(13)		41.429	(13)		36.773	(13)	
McFadden Pseudo R-sq.	0.113			0.115			0.026			0.023		

Note: ***, **, * = significant at the 1, 5, 10% level

Tab. 10. Results of the probit of manure spreading, separately by nature of the livestock

	Model 1						Model 2					
	Dairy farms			Other			Dairy farms			Other		
	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.
Constant	1.356***	9.242		1.48***	9.714		1.319***	9.002		1.434***	9.234	
Standard Output (Meuro)	-0.702***	-2.606	-0.159	-0.442**	-2.522	-0.081	-0.413**	-2.253	-0.094	-0.356***	-2.637	-0.065
St. Output squared	0.085	1.449	0.019	0.018	1.027	0.003						
N. bovine heads	0.000	0.869	0.000	-0.000	-0.837	-0.000	0.000	0.413	0.000	0.000	0.424	0.000
N. bovine heads squared							0.000	0.017	0.000	0.000	-1.365	-0.000
Organic (0-1)	0.245**	1.999	0.049	0.232*	1.659	0.037	0.250**	2.037	0.050	0.228	1.632	0.037
Computer (0-1)	-0.098	-1.379	-0.023	0.010	0.131	0.002	-0.111	-1.567	-0.026	-0.009	-0.127	-0.002
Web (0-1)	0.005	0.040	0.001	0.150	1.000	0.025	0.009	0.075	0.002	0.164	1.082	0.027
Internet (0-1)	-0.342**	-2.241	-0.091	-0.227	-1.469	-0.047	-0.351**	-2.302	-0.094	-0.229	-1.484	-0.048
Hills (0-1)	-0.348***	-7.194	-0.084	-0.006	-0.137	-0.001	-0.343***	-7.041	-0.083	0.002	0.034	0.000
Mountains (0-1)	-0.079	-1.443	-0.018	-0.016	-0.256	-0.003	-0.069	-1.264	-0.016	-0.004	-0.057	-0.001
Operator's age (yrs)	-0.001	-0.367	0.000	-0.002	-0.844	0.000	0.000	-0.207	-0.000	-0.001	-0.649	0.000
Gender (1=F)	0.024	0.478	0.005	0.063	1.158	0.011	0.032	0.629	0.007	0.076	1.370	0.014
Education (years)	-0.009	-0.978	-0.002	-0.016*	-1.673	-0.003	-0.009	-0.968	-0.002	-0.016	-1.630	-0.003
Agricultural education (0-1)	-0.103	-0.956	-0.024	0.185*	1.709	0.031	-0.110	-1.023	-0.026	0.181	1.669	0.030
N. Observations	6,101			6,651			6,101			6,651		
Log-Likelihood	-2,509.071			-2,249.575			-2,510.141			-2,248.916		
Chi-sq (d.f.)	90.407	(13)		44.548	(13)		88.266	(13)		45.866	(13)	
McFadden Pseudo R-sq.	0.018			0.010			0.017			0.010		

Note: ***, **, * = significant at the 1, 5, 10% level

Tab. 11. Results of the probit of manure spreading with quick incorporation, separately by nature of the livestock

	Model 1						Model 2					
	Dairy farms			Other			Dairy farms			Other		
	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.
Constant	-1.209***	-6.753		-1.048***	-7.251		-1.214	-6.765		-1.039***	-7.189	
Standard Output (Meuro)	0.718	1.611	0.106	1.253***	3.737	0.283	0.003	0.013	0.000	-0.008	-0.088	-0.002
St. Output squared	-0.667*	-1.692	-0.098	-0.936***	-3.125	-0.211						
N. bovine heads	0.000	0.736	0.000	0.000	-0.135	-0.747D-05	0.001**	2.509	0.000	0.001***	3.608	0.000
N. bovine heads squared							-0.000*	-1.878	-0.000	-0.000***	-2.649	-0.000
Organic (0-1)	-0.081	-0.502	-0.011	0.128	1.069	0.031	-0.083	-0.513	-0.012	0.143	1.193	0.036
Computer (0-1)	0.099	1.284	0.015	0.025	0.383	0.006	0.096	1.243	0.015	0.032	0.496	0.008
Web (0-1)	0.116	0.814	0.018	-0.028	-0.208	-0.006	0.129	0.905	0.021	0.005	0.037	0.001
Internet (0-1)	-0.066	-0.327	-0.009	-0.335**	-2.053	-0.063	-0.072	-0.362	-0.010	-0.333**	-2.046	-0.065
Hills (0-1)	-0.265***	-5.089	-0.037	-0.010	-0.249	-0.002	-0.259***	-4.932	-0.036	0.004	0.111	0.001
Mountains (0-1)	-0.935	-12.317	-0.109	-0.789***	-10.583	-0.132	-0.929***	-12.196	-0.109	-0.790***	-10.584	-0.137
Operator's age (yrs)	0.004*	1.944	0.001	0.001	0.412	0.000	0.004*	1.942	0.001	0.001	0.373	0.000
Gender (1=F)	-0.025	-0.390	-0.004	0.013	0.252	0.003	-0.025	-0.389	-0.004	0.002	0.030	0.000
Education (years)	-0.016	-1.381	-0.002	0.004	0.437	0.001	-0.015	-1.315	-0.002	0.006	0.625	0.001
Agricultural education (0-1)	0.217*	1.807	0.037	-0.011	-0.117	-0.002	0.219*	1.823	0.037	-0.005	-0.051	-0.001
N. Observations	6,101			6,651			6,101			6,651		
Log-Likelihood	-1,812.778			-2,861.199			-1,812.660			-2,863.870		
Chi-sq (d.f.)	274.333	(13)		201.258	(13)		274.567	(13)		195.917	(13)	
McFadden Pseudo R-sq.	0.070			0.034			0.070			0.033		

Note: ***, **, * = significant at the 1, 5, 10% level

Tab. 12. Results of the probit of slurry spreading, separately by nature of the livestock

	Model 1						Model 2					
	Dairy farms			Other			Dairy farms			Other		
	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.	Coeff.	t-ratio	Marg. eff.
Constant	-0.134	-0.962		0.314**	2.457		-0.046	-0.334		0.169	1.296	
Standard Output (Meuro)	1.426***	5.201	0.423	0.127	0.712	0.042	-0.050	-0.287	-0.015	-0.144	-1.170	-0.047
St. Output squared	-0.951***	-4.894	-0.282	-0.073**	-2.115	-0.024						
N. bovine heads	0.001***	3.866	0.000	0.000*	1.930	0.000	0.002***	6.985	0.001	0.002***	6.630	0.001
N. bovine heads squared							-0.000***	-6.243	-0.000	-0.000***	-5.344	-0.000
Organic (0-1)	-0.130	-1.162	-0.037	-0.113	-1.025	-0.036	-0.129	-1.154	-0.037	-0.107	-0.971	-0.034
Computer (0-1)	0.148**	2.324	0.046	0.056	0.956	0.019	0.166***	2.617	0.052	0.016	0.270	0.005
Web (0-1)	-0.003	-0.026	-0.001	-0.010	-0.081	-0.003	0.010	0.084	0.003	0.023	0.192	0.008
Internet (0-1)	-0.222	-1.381	-0.060	-0.275*	-1.952	-0.083	-0.211	-1.315	-0.058	-0.285**	-2.019	-0.085
Hills (0-1)	-0.404***	-9.107	-0.113	-0.513***	-13.794	-0.162	-0.410***	-9.255	-0.115	-0.483***	-12.857	-0.152
Mountains (0-1)	-0.496***	-10.110	-0.135	-0.585***	-11.136	-0.167	-0.510***	-10.442	-0.139	-0.547***	-10.341	-0.157
Operator's age (yrs)	-0.007***	-4.468	-0.002	-0.008***	-5.286	-0.003	-0.008***	-4.921	-0.002	-0.007***	-4.537	-0.002
Gender (1=F)	0.023	0.487	0.007	-0.225***	-4.930	-0.071	0.003	0.060	0.001	-0.190***	-4.128	-0.060
Education (years)	-0.020**	-2.297	-0.006	-0.025***	-3.027	-0.008	-0.019**	-2.210	-0.006	-0.023***	-2.820	-0.008
Agricultural education (0-1)	0.120	1.203	0.037	-0.021	-0.240	-0.007	0.136	1.371	0.043	-0.030	-0.344	-0.010
N. Observations	6,101			6,651			6,101			6,651		
Log-Likelihood	-3,096.224			-3,759.988			-3,108.457			-3,739.136		
Chi-sq (d.f.)	475.417	(13)		387.654	(13)		450.951	(13)		429.357	(13)	
McFadden Pseudo R-sq.	0.071			0.049			0.068			0.054		

Note: ***, **, * = significant at the 1, 5, 10% level

Tab. 13. Results of the probit of slurry spreading incorporated within 24 hours, separately by nature of the livestock

	Model 1						Model 2					
	Dairy farms			Other			Dairy farms			Other		
	Coeff.	t-ratio	Marg.eff.	Coeff.	t-ratio	Marg.eff.	Coeff.	t-ratio	Marg.eff.	Coeff.	t-ratio	Marg.eff.
Constant	-1.351***	-6.040		-1.801***	-7.109		-1.346***	-6.016		-1.980***	-7.545	
Standard Output (Meuro)	1.124***	2.960	0.071	1.204**	2.436	0.046	-0.032	-0.127	-0.002	0.027	0.269	0.001
St. Output squared	-0.917***	-3.688	-0.058	-0.616*	-1.659	-0.024						
N. bovine heads	0.001***	2.983	0.000	0.000	-0.289	-0.000	0.003***	5.366	0.000	0.003***	3.630	0.000
N. bovine heads squared							-0.000***	-3.302	-0.000	-0.000***	-2.680	-0.000
Organic (0-1)	-0.387	-1.253	-0.017	-0.004	-0.015	0.000	-0.417	-1.325	-0.018	0.084	0.327	0.003
Computer (0-1)	0.162*	1.851	0.012	0.075	0.722	0.003	0.157*	1.783	0.011	0.075	0.726	0.003
Web (0-1)	-0.163	-0.867	-0.009	0.033	0.154	0.001	-0.160	-0.848	-0.009	0.048	0.218	0.002
Internet (0-1)	-0.301	-1.111	-0.014	0.121	0.517	0.005	-0.333	-1.214	-0.015	0.146	0.627	0.006
Hills (0-1)	-0.710***	-9.376	-0.037	-0.649***	-7.452	-0.022	-0.700***	-9.213	-0.037	-0.613***	-6.972	-0.020
Mountains (0-1)	-1.091***	-9.444	-0.052	-1.167***	-5.083	-0.023	-1.084***	-9.360	-0.052	-1.147***	-4.915	-0.022
Operator's age (yrs)	-0.003	-0.948	0.000	-0.002	-0.559	-0.000	-0.003	-1.002	0.000	0.000	-0.075	-0.000
Gender (1=F)	-0.214**	-2.141	-0.012	-0.062	-0.595	-0.002	-0.212**	-2.122	-0.012	-0.046	-0.438	-0.002
Education (years)	0.003	0.238	0.000	0.015	0.934	0.001	0.004	0.310	0.000	0.019	1.214	0.001
Agricultural education (0-1)	0.162	1.182	0.012	-0.314*	-1.759	-0.009	0.162	1.178	0.012	-0.320*	-1.790	-0.009
N. Observations	6,101			6,651			6,101			6,651		
Log-Likelihood	-1,046.705			-726.991			-1,045.379			-723.476		
Chi-sq (d.f.)	416.152	(13)		142.861	(13)		418.804	(13)		149.890	(13)	
McFadden Pseudo R-sq.	0.166			0.089			0.167			0.0939		

Note: ***, **, * = significant at the 1, 5, 10% level

Tab. 14. Results of the probit of slurry spreading incorporated quickly, separately by nature of the livestock

	Model 1						Model 2					
	Dairy farms			Other			Dairy farms			Other		
	Coeff.	t-ratio	Marg.eff.	Coeff.	t-ratio	Marg.eff.	Coeff.	t-ratio	Marg.eff.	Coeff.	t-ratio	Marg.eff.
Constant	-1.858***	-6.088		-1.799***	-7.106		-1.872***	-6.105		-1.975***	-7.536	
Standard Output (Meuro)	0.962	1.374	0.032	1.208**	2.446	0.046	0.063	0.171	0.002	0.026	0.266	0.001
St. Output squared	-0.845	-1.384	-0.028	-0.621*	-1.669	-0.024						
N. bovine heads	0.001	1.058	0.000	0.000	-0.300	-0.000	0.002**	2.433	0.000	0.003***	3.604	0.000
N. bovine heads squared							0.000	-1.508	-0.000	-0.000***	-2.659	-0.000
Computer (0-1)	0.135	1.127	0.005	0.084	0.816	0.003	0.128	1.064	0.005	0.086	0.845	0.003
Web (0-1)	-0.054	-0.233	-0.002	0.058	0.275	0.002	-0.048	-0.204	-0.001	0.087	0.412	0.003
Hills (0-1)	-0.256***	-2.689	-0.008	-0.649***	-7.458	-0.022	-0.245***	-2.556	-0.007	-0.610***	-6.960	-0.020
Mountains (0-1)	-0.670***	-4.813	-0.017	-1.167***	-5.096	-0.023	-0.655***	-4.690	-0.017	-1.140***	-4.901	-0.022
Operator's age (yrs)	-0.004	-1.025	0.000	-0.002	-0.584	-0.000	-0.004	-1.011	0.000	0.000	-0.115	-0.000
Gender (1=F)	0.054	0.470	0.002	-0.062	-0.602	-0.002	0.056	0.484	0.002	-0.046	-0.437	-0.002
Education (years)	-0.003	-0.139	-0.000	0.015	0.949	0.001	-0.002	-0.107	-0.000	0.020	1.247	0.001
Agricultural education (0-1)	0.140	0.747	0.005	-0.307*	-1.731	-0.009	0.141	0.753	0.005	-0.310*	-1.745	-0.008
N. Observations	6,101			6,651			6,101			6,651		
Log-Likelihood	503.875			-727.121			-503.372			-723.731		
Chi-sq (d.f.)	69.646	(11)		142.601	(11)		70.652	(11)		149.381	(11)	
McFadden Pseudo R-sq.	0.065			0.089			0.066			0.094		

Note: ***, **, * = significant at the 1, 5, 10% level

Tab. 15. Results of the probit of slurry band spreading, separately by nature of the livestock

	Model 1						Model 2					
	Dairy farms			Other			Dairy farms			Other		
	Coeff.	t-ratio	Marg.eff.	Coeff.	t-ratio	Marg.eff.	Coeff.	t-ratio	Marg.eff.	Coeff.	t-ratio	Marg.eff.
Constant	-2.219***	-5.299		-2.331***	-7.585		-2.152***	-5.174		-2.310***	-7.404	
Standard Output (Meuro)	1.398	1.617	0.023	0.876***	2.095	0.030	0.177	0.498	0.003	0.114	1.111	0.004
St. Output squared	-0.794	-1.146	-0.013	-0.163	-1.092	-0.006						
N. bovine heads	0.000	-0.082	-0.000	-0.001	-1.331	-0.000	0.001	1.193	0.000	0.000	0.200	0.000
N. bovine heads squared							0.000	-0.968	-0.000	0.000	-0.358	-0.000
Computer (0-1)	0.466***	3.202	0.012	0.046	0.323	0.002	0.483***	3.312	0.013	0.071	0.509	0.003
Internet (0-1)	-0.084	-0.224	-0.001	0.086	0.283	0.003	-0.071	-0.191	-0.001	0.078	0.255	0.003
Hills (0-1)	-0.277**	-1.976	-0.004	0.031	0.342	0.001	-0.280***	-1.992	-0.004	0.032	0.343	0.001
Mountains (0-1)	-0.172	-1.161	-0.003	0.213*	1.895	0.009	-0.178	-1.200	-0.003	0.205*	1.811	0.008
Operator's age (yrs)	-0.001	-0.258	-0.000	0.003	0.796	0.000	-0.002	-0.363	-0.000	0.003	0.752	0.000
Gender (1=F)	-0.220	-1.203	-0.003	-0.243**	-2.016	-0.007	-0.236	-1.297	-0.003	-0.258**	-2.133	-0.008
Education (years)	-0.024	-0.870	0.000	-0.007	-0.382	0.000	-0.024	-0.860	0.000	-0.006	-0.316	0.000
Agricultural education (0-1)	-0.186	-0.589	-0.002	-0.173	-0.727	-0.005	-0.176	-0.556	-0.002	-0.165	-0.694	-0.005
N. Observations	6,101			6,651			6,101			6,651		
Log-Likelihood	-264.990			-494.879			-265.959			-496.665		
Chi-sq (d.f.)	40.415	(11)		14.578	(11)		38.478	(11)		11.006	(11)	
McFadden Pseudo R-sq.	0.071			0.015			0.067			0.011		

Note: ***, **, * = significant at the 1, 5, 10% level