Effect of uncertainty on farmers decision making: case of animal manure use

Vermeire Bert – Viaene Jacques – Gellynck Xavier

Ghent University, Department of Agricultural Economics
Coupure Links 653, 9000 Ghent, Belgium

1. Introduction

Due to the high levels of manure application and the poor use efficiency of manure, the European agriculture is held responsible for a considerable negative impact on surface water quality (*Langeveld* et al., 2007). This problem has emerged particularly in Western-European countries such as the UK, Belgium, The Netherlands and Denmark, facing a large expansion and intensification process in the livestock production since the 1960s (*Van der Straeten* et al., 2008). Policy measures related to the application of manure on the land encompass two major measures: emission rights, understood as the amount of nutrients which can be applied on the land, differentiated by crop and the N spreading calendars, whereby the manure can only be applied when the crop needs nutrients. The fundamental aim of this pillar is to maximising application rate while avoiding overfertilisation. Maximizing the application rate is related to the economic sustainability of the agricultural sector, by altering the manure surplus, while avoiding overfertilisation is imperative in enhancing ecological sustainability, by preventing nitrate leaching to surface and soil waters. For nitrate policy to meet its target, the farmers should not exceed their emission rights, however make optimal use of their emission right for manure. Consequently, the successful implementation of sink-related measures will strongly depend of the absorptive capacity of farmers towards new ways of nutrient management in general and of animal manures in particular.

The concept of absorptive capacity dates back to the seminal work of Cohen and Levinthal in the early 1990s, who defined it as “the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends” (1990). In this paper, this concept is applied to agriculture. This is different from a vast stream of absorptive capacity studies which focus on innovation or overall performance measures as outcome of absorptive capacity (*Lane et* al., 2006). This is a narrowed focus in compared to the initial work of Cohen & Levinthal, which stressed the general commercial application of knowledge (1990). As a consequence, *Lane* et al. argue that absorptive capacity should also be explored in non-R&D contexts (2006). Sustainable farming is indeed a case where absorptive capacity is relevant. In fact, the adoption of sustainable farming practices can be considered complex, knowledge intensive and non-prescriptive. This goes beyond the classical notion of knowledge transfer to- and adoption by farmers and moves towards learning based on social interaction (*Ingram,* 2008). Moreover, it is stated that the adoption of new agricultural practices requires autonomous learning instead of the reliance on standardised external knowledge (*Morgan and Murdoch,* 2000). This suggests that the challenge for contemporary extension lies in enhancing the realised absorptive capacity and moving beyond pure acquisition of standardized knowledge.

Absorptive capacity and uncertainty are strongly linked. Uncertainty plays a crucial role both in new innovation development and in the adoption of innovations. Recently, many authors have stressed the role of uncertainty in environmental innovations (*Meijer* et al., 2007; *Pannell* et al., 2006; *Serra* et al., 2008; *Torkamani*, 2005). Some authors argue that the risk involved with environmental innovations is higher as failure does not only have effect on sales but also on future production (environmental degradation) and threatens their licence-to-produce (*Vanclay,* 2004). Specifically related to the use of animal manures following kinds of uncertainty have been identified in literature:

- Policy uncertainty which manifests itself in a double way: on the one hand changes in the regulatory framework may force changes in the production process, on the other hand the farmer’s choices regards the regulatory framework (e.g. tradable quota) suffer from uncertainty’s in the farm’s production level and in its production environment (*Lehtonen* et al., 2007; *Wossink and Gardebroek,* 2006).
- Effect of climate conditions on nitrate leaching (*Chambers* et al., 2000; *Sheriff,* 2005)
- Within-parcel and site-to-site variability in nitrification, surface runoff, volatilization and leaching (*Sheriff,* 2005).
- Uncertainty with respect to the exactness of analytical techniques. This relates to the fact that knowledge about some processes is still limited and that most models rely on the quality of data collection and may suffer from measurement errors (*Oenema* et al., 2003).

Therefore this paper investigates to what extent the perceived uncertainty about the use of animal manures affects the farmers' absorptive capacity and how this finally results in higher satisfaction about external knowledge provision. In particular our research will focus on the late-adopters, specified as farmers exhibiting low animal manure use.

The research investigates two research hypotheses:

1. Perceived uncertainty has a negative effect on the absorptive capacity towards animal manure use.
2. Absorptive capacity towards animal manure use has a positive effect on the satisfaction about external knowledge provision.

2. Research method

Partial-Least Squares (PLS) path modelling allows to link absorptive capacity to its determining factors (uncertainty and control variables) on the one hand and to its outcome (satisfaction with knowledge provision) on the other, within one statistical model. A PLS path model consists of two models: a structural model, defining the relationship between latent variables and a measurement model, linking latent variables with a set of manifest variables (outer model) (*Tenenhaus* et al., 2005a). The structural model situates different latent variables within a causal chain. PLS path modelling is capable of analysing complex relations with many latent variables. The measurement model describes the latent variables indirectly, by blocks of observable variables. There are two possible relations between the latent and manifest variables: reflective and formative (*Coltman* et al., 2008; *Tenenhaus* et al., 2005b).

The PLS path model analysis is applied by the following steps. First, qualitative research methods (focus groups and expert-interviews) are applied to develop relevant scales for the studied concepts. Second, a survey is implemented to measure farmers' relation with the concepts. Third, cluster analysis is done in order to make a segmentation in terms of famers' manure use. Fourth, a PLS path model is developed and tested in order to answer the research hypotheses.

3. Analysis

3.1. Defining manure use profiles by cluster analysis

The nutrient strategy of arable farmers is characterised as a trade-off between animal manure and chemical fertilisers, each having both agronomic, economic and environmental advantages and disadvantages. By means of cluster analysis the farms are classified into four groups with an optimal internal resemblance, based on a set of variables that indicate the trade-off between manure and fertiliser[1] (*De Pelsmacker and Van Kenhove,* 2005; *Malhotra* et al., 2005). Cluster variables are the application rates for manure and fertiliser. The application rate is the proportion of the amount of applied N to the maximum admissible application right for N. The application rate for manure also included other organic nutrients (until 2005), which only represent a fraction of the total amount of applied organic N.

1 Data source: FLA, 2007

The results of the cluster analysis are summarised in *Figure 1.* A four-cluster solution is obtained. Clusters are labelled as manure users, varied users, fertiliser users and non-users. The analysis has also been made for the total Flemish population of farmers with low application rates, which permits to evaluate representativeness. The sample clusters indeed are representative in terms of size and cluster centres. For the fertiliser users in the sample the application rate for chemical fertiliser is slightly higher than in the whole of Flanders.

By interpreting the application rates of each of the clusters and describing them by FLA data the clusters can be interpreted as follows:

Manure users

The nutrient strategy of these farmers is almost entirely based on animal (and other) manures, although their application right is still below the Flemish average. Consequently the application rate for chemical fertilisers is very low. On average, these companies have an own production of 5.200 Kg. N. in 2005, of which 3400 Kg. was exported from the farm. It concerns mainly pig and cattle manure. Correspondingly, these farms primarily produce feed crops (grassland and corn). These farms own application rights and even own manure production, but obtain a lower application rate compared to the overall average. This can not be explained by a preference for chemical fertilisers, which is even lower. Consequently, this cluster relies almost entirely on manures.

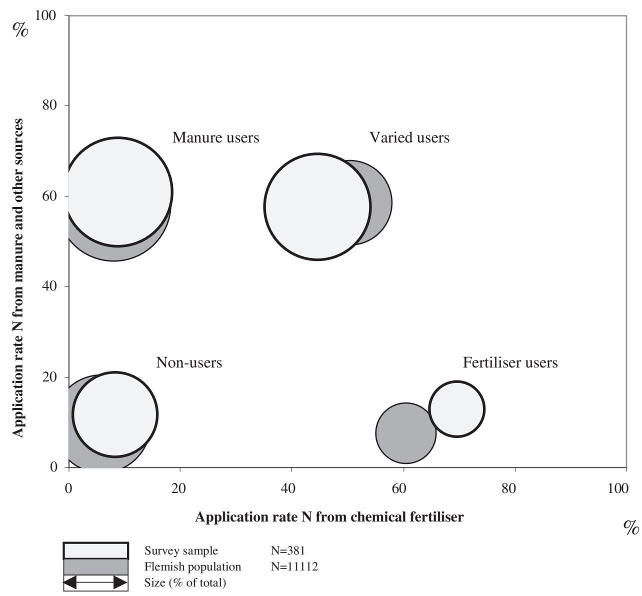

Figure 1: Application rates and size of user profiles within survey sample and Flemish population of farmers with manure application rate below average (for N), 2005

Diversified users

These farms make use of both nutrients from manures (application rate 58%) and chemical fertilisers and from chemical fertilisers (45%). This cluster is specialised in the production of cereals in combination with corn and grassland. On average, these are the largest farms, both in terms of maximum admissible application right as in terms of average surface (30 ha.). On average, they have a negative manure surplus of -817 Kg N.

Chemical nitrogen users

This is the smallest cluster, primarily using chemical fertilisers, for which they have an application rate of 70%. This group is specialised in arable farming and a variety of other crops, in particular fruit and horticulture. These farms have the lowest maximum admissible application rights.

Non-users

This is a heterogeneous group with low application rates for all manure types, e.i. hardly using nutrients at all. On the one hand, these farms have a low average surface area (15 ha.) but on the other hand a high production of pig manure (2600 kg N) which is, however, not significantly different from the other nutrient use profiles. As such, this group includes a limited number of large scale pig farms with limited arable land. In line with this, on average about 4188 Kg out of 4300 Kg N manure production is exported from the farm (in 2005). Further, this nutrient use profile consists of arable farms with diverse crop specialisations.

3.2. Building the PLS path model

Following the research hypotheses and the theoretical framework, absorptive capacity, uncertainty and satisfaction with external knowledge provision are the main latent variables in our model. Further, three control variables are included in the analysis, for which existing theory demonstrates a relationship with absorptive capacity. Hereby, the impact of uncertainty will be measured against these variables. The model is depicted in *Figure 2*.

Data for the main latent variables are drawn from the survey, while the control variables combine data from the FLA with a few survey variables. The latent variables are defined as sets of manifest variables as follows. The variables and mean scores are described in *Table 3* in annex and is referred to by *Figure 2.* In the formative constructs of the model three pairs of variables exhibit high inter-item correlation. To prevent multicollinearity these variables were transformed into three factor scores.

Absorptive capacity is modelled as a reflective construct consisting of variables referring to the three moments of absorptive capacity as distinguished by *Cohen and Levinthal* (1990): valuing new external information, assimilating it, and applying it. The selected variables refer to different aspects of manure management. By implementing these variables in a reflective construct the underlying dimension, absorptive capacity, is measured. The variables relate to the evaluation of technological knowledge, learning about manure policy and nutrient management, the feasibility of planning crop succession for optimal nutrient uptake, the motivation for nutrient management and its effect on the complexity of work.

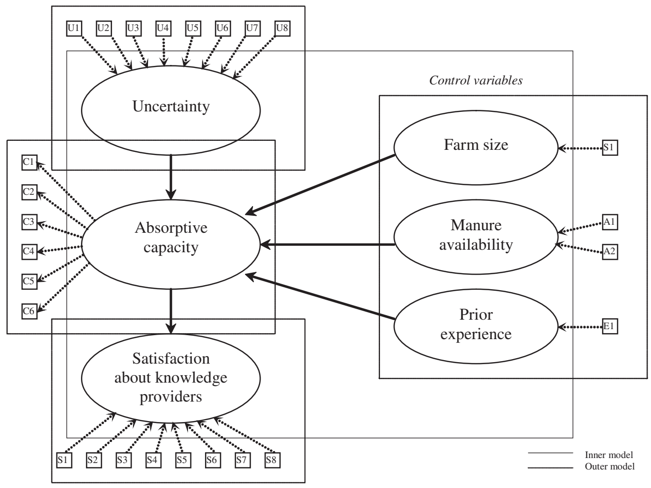

Figure 2: Conceptual framework

Uncertainty and satisfaction about knowledge providers are modelled as a formative constructs, whereby the reliability of the constructs is supported by the explorative qualitative research stage. Although this sufficiently underpins their relevance, their exhaustiveness can not be presupposed. Observing the variables the expectation is that some variables are correlated and others not. By modelling these latent variables formatively rather than reflectively, later analysis will reveal differences in loading of the manifest variables on the latent variable. Uncertainty refers to types of uncertainty: policy uncertainty (affecting investment decisions and the risk of penalties), agronomical uncertainty (climate uncertainty, autumn mineralisation and historical factors in the parcel) and the variability of manure- and soil analysis results, depending of the lab, the timing and place of sampling. Satisfaction with knowledge provision encompasses government communication: its effect on manure use, its transparency and amount of initiatives, information leaflets, personal advice and the activities of the FLA. However, reference is also made to fertilisation advices (public or private) and advice of suppliers and customers. A final variable indicates the willingness-to-pay for manure- and soil analysis.

The control variables refer to farm size, manure availability and prior experience. Farm size is understood as the surface area. Manure availability is measured by production pressure, being the net production of animal manure per ha. in the community where the farm is located. However, as this measure ignores the possibility of transport to neighbouring regions, this variable is complemented with a survey measure (*Van der Straeten* et al., 2009). Prior experience is measured by the manure application rate for animal manure in 2005 and the percentage of surface area in vulnerable areas in 2005. As indicated earlier, in 2007 the new Manure Action Plan generalized the emission rights in vulnerable areas to the entire Flemish area. Consequently, farmers which had a higher percentage of vulnerable area had a higher prior experience with the new legal situation by the time the legislation change occurred.

3.3. Testing the model

The model is applied to four manure use profiles. It is expected that the model's predictive power will be different for each profile, as the knowledge absorption is assumed to be correlated to trade-off between animal manures and chemical fertilisers. The evaluation of a PLS path model follows three stages: first, quality criteria for the measurement model are evaluated. Second, the effects of the inner model are interpreted and finally, the outer model is interpreted. The significance of the effects is verified by the bootstrap procedure.

Table 1: Evaluation of absorptive capacity (applied to four models)

	Inner model			Outer model		
	Path coeffi-cient	Boot-strap t-value	R^2	AVE	Cron-bach's Alpha	Com-posite reliability
Manure users	0,416	5,442	0,388	0,640	0,726	0,912
Varied users	0,637	9,873	0,302	0,558	0,734	0,881
Fertiliser users	0,720	13,774	0,538	0,521	0,709	0,863
Non-users	0,462	6,144	0,380	0,410	0,614	0,790
t-value	sig. > 2					

Our measure for absorptive capacity can be evaluated by three criteria, as depicted in *Table 1.* The average variance extracted (AVE) is the amount of variance that is captured by the construct in relation to the variance that is captured by measurement error (*Fornell and Larcker,* 1981). Except for the non-users our measurement model for absorptive capacity fulfils the AVE-criterion for both reliability and discriminant validity. Two other measures reflecting internal consistency are composite reliability and Cronbach's Alpha, where the threshold is 0,7 (*Hulland,* 1999). For composite reliability, all user profiles pass the threshold, while the non-users do not pass the threshold for Cronbach's Alpha (0,614). This, together with the poor AVE, implies that our construct for absorptive capacity is not relevant for farmers who do not use any nutrients, or that it is multidimensional. Indeed it could be argued that if farmers do not use nutrients at all, the variables with respect to learning about manure are perceived less relevant by the respondent. On the other hand, multidimensionality could also play a role as this cluster encompasses a number of cattle farms with land which is not actively used. The reliability of formative construct relies on theory. In this research the relevance of the formative constructs is supported by the qualitative research (focus groups and expert interviews) which resulted in an identification of bottlenecks for using manure. This supports the relevance of the variables in the model but does not guarantee exhaustiveness. Conclusions about the latent variables should therefore be restricted to the aspects of uncertainty covered by the manifest variables.

The effects between the manifest variables in the inner model are evaluated by the R^2 and the path coefficients. The path coefficients should be understood as standardized linear regression coefficients representing possible causal linkages between the latent variables. As the analysis makes use of four distinct models with four distinct sets of path coefficients and indicator loadings, one should be cautious in comparing them between user profiles in absolute figures as the size of each coefficient is relative to the set of coefficients within the model. The significance of the path coefficients is assessed by the bootstrap t-values, which should be higher than 2.

The four models exhibit moderate potential to explain farmers' absorptive capacity, with R^2 ranging between 0,302 and 0,538 (see Table 1). It is clear that the models do not permit accurate prediction of absorptive capacity, for which an R^2 higher than 0,5 is recommended. This criterion has been met for the fertiliser users (0,538) but is below 0,4 for the other profiles. However, as the main aim is to test the role of uncertainty and not to offer the full explanation of absorptive capacity, this is no obstacle for developing research findings about manure users as well as non-users.

Uncertainty has a strong negative effect on farmers' perceived absorptive capacity, as depicted in

Table 2: Evaluation of the formative latent variables (applied to four models)

	Path coefficient	Bootstrap t-value	R^2
Satisfaction knowledge providers			
Manure users	*n.a.*	*n.a.*	0,173
Varied users	*n.a.*	*n.a.*	0,406
Fertiliser users	*n.a.*	*n.a.*	0,519
Non-users	n.a.	n.a.	0,213
Uncertainty			
Manure users	-0,583	8,794	*n.a.*
Varied users	-0,520	6,757	*n.a.*
Fertiliser users	-0,523	5,029	*n.a.*
Non-users	-0,603	5,172	*n.a.*
Farm size			
Manure users	0,186	2,423	*n.a.*
Varied users	0,109	1,585	*n.a.*
Fertiliser users	0,256	3,691	*n.a.*
Non-users	0,062	1,254	*n.a.*
Availability of manure			
Manure users	0,046	0,712	*n.a.*
Varied users	0,101	1,338	*n.a.*
Fertiliser users	-0,133	1,614	*n.a.*
Non-users	-0,033	0,451	*n.a.*
Prior experience			
Manure users	-0,090	1,308	*n.a.*
Varied users	0,081	1,101	*n.a.*
Fertiliser users	-0,344	3,657	*n.a.*
Non-users	-0,122	1,181	*n.a.*
t-value sig. > 2 n.a. not applicable			

Table 3: description of the manifest variables (One-way ANOVA)

	Mean scores				
	Manure users	Varied users	Fertiliser users	Non-users	Sig.
Satisfaction knowledge providers					
"If government would communicate better this would not have effect on my animal manure use"	2,59	2,69	2,44	2,69	,636
"Fertilization advices are sufficiently detailed to achieve a good result"	3,42	3,58	3,83	3,55	,197
"I know which public knowledge partner I should address with my questions"	2,75	2,79	2,50	2,72	,651
"I can address my suppliers and customers for various advice"	2,71	2,58	2,89	2,53	,333
"The personal support by public institutes is a good help"	3,23	2,86	2,92	2,97	,033**
"The Flemish Land Agency should put more effort in counselling farmers"	1,83	1,74	1,94	1,91	,484
"The amount of extension activities is appropriate for having an overview over available information"	3,12	3,07	3,08	2,94	,621
"The price of manure- and soil analysis is not a burden for making use of these techniques"	2,24	2,15	2,52	2,33	,375
Absorptive capacity					
"I succeed in comparing and assessing different available technologies"	2,99	2,91	2,88	2,82	,698
"I succeed in planning crop succession in order to optimize nutrient uptake"	2,46	2,33	2,72	2,36	,274
"I can deal with the increased complexity of work which follows from manure issues"	2,10	1,94	2,22	1,97	,418
"I succeed in remaining up-to-date about manure policy"	2,68	2,58	2,80	2,69	,779
"I succeed in remaining up-to-date about nutrient management techniques"	2,96	2,90	3,22	3,22	,246
"The difficulty of nutrient management does not discourage me"	2,88a	2,83a	3,42b	2,66a	,030**
Uncertainty					
"I would use more animal manure if the result was more predictable"	3,72	3,62	3,83	3,49	,311
"Because of the risk on penalties and income loss I choose to use less animal manure than my crop can take"	4,07	4,01	3,92	3,82	,443
"Due to the frequent changes in manure policy I am more reluctant to take investment decisions"	3,72	3,79	3,69	3,91	,566
"Climate unpredictability has great effect on nitrate leaching on my parcels"	4,11a	4,36a	4,14a	4,05a	0,045**
"Past activities on my parcel are influencing my nutrient management result up to date"	3,27	3,29	3,22	3,28	,305
"I experience strong variability in manure- & soil analysis results between labs"	3,24	3,29	3,22	3,28	,956
"I experience strong variability in soil analysis results depending of place & timing of sampling"	3,52a	3,83a	3,75a	3,65a	,045**
"I do no trust manure transporters"	2,56	2,50	2,50	2,37	,620
Farm size					
Surface are in 2005 (ha.)	22,54bc	29,30c	18,92ab	15,07a	,000**
Availability of manure					
Production pressure of animal manures per community	218,85b	186,14b	118,49a	215,87b	,000**
Manure available in region	2,04	1,94	2,25	2,10	,439
Prior experience					
Manure application rate in 2005	61,06b	57,50b	9,42a	12,19a	,000**
Pct. vulnerable area in 2005	40,96	47,16	38,29	49,00	,424

Sig. < 0,05
Letters in superscript indicate subgroups with significantly different mean scores (Duncan's Post-hoc Test)

Table 2. The higher importance attributed to uncertainty factors, the lower the perceived absorptive capacity will be. This holds true for all four user profiles, but the effect is strongest for the manure users and non-users. These are the profiles which rely on animal manures primarily, showing that uncertainty increases with reliance on animal manure. The profiles also using chemical fertiliser (varied- and fertiliser users) have a lower path coefficient. However, for fertiliser users this coefficient should be interpreted as high, as it could be assumed that their very low animal manure use would result in lower importance of uncertainty factors specific to animal manure.

In our model the effect of uncertainty is stronger than of the control variables. Farm size has a moderate, but highly significant positive impact on the absorptive capacity of manure- and fertiliser users. Further, prior experience with animal manure in 2005 has a negative impact on fertiliser users' absorptive capacity today (-0,344). There is no significant impact of manure availability on absorptive capacity. As such, the proximity of manure producing farms does necessarily stimulate learning among farmers with low application rates.

Absorptive capacity has a positive effect on the satisfaction with external knowledge provision. Alternatively, the poor absorptive capacity of some farmers explains why they are not satisfied about the available knowledge. The effect is significant for all four user profiles, but it is strongest for the varied users and fertiliser users. This is striking as these are the user profiles which also make use of chemical fertiliser intensively. Considering that most variables measuring satisfaction with extension are related to nutrient management in general and not manure specifically, this indicates that knowledge absorption about animal manures is also beneficial for farmers combining both nutrient sources.

4. Conclusion

The negative effects of uncertainty and on perceived absorptive capacity indicates that identified problems with respect to the use of animal manures do not motivate farmers to search for external knowledge in order to solve these problems but, in contrary, they will be less inclined to learn about better ways to make use of manure. Furthermore, this will make them also less satisfied about the external knowledge which is offered and particularly will make them less willing to invest in soil analysis techniques which could help them to develop a more reliable nutrient management.

These conclusions are problematic for policy makers, counsellors and consultants.

First of all, while uncertainty could lead to problem identification and start a learning process in some contexts, it might discourage all learning in others, such as in the case of manure use. Policy makers should be aware that uncertainty following policy changes might lead to diminishing capacity of farmers to adapt to these changes and eventually lead to undesired effects of the measure.

Second, while extension is the main instrument to help farmers adapt to the changing production environment, farmers with low absorptive capacity – being the main target group for these actions – will be less open towards these extension activities. This shows that more policy attention should be devoted to enhancing the learning skills and openness towards external knowledge.

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