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Farmers' Preferences For Bluetongue Vaccination Scheme Attributes: An Integrated Choice and Latent Variable Approach

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Abstract

Re-emergence of the bluetongue disease in Europe poses a continuous threat to European livestock production. Large-scale vaccination is the most effective intervention to control virus spread. Compared to command-and-control approaches, voluntary vaccination approaches can be effective at lower costs, provided that farmers are willing to participate. We use a discrete choice experiment to estimate the preferences for vaccination scheme attributes, accounting for preference heterogeneity via an integrated choice and latent variable approach. In designing livestock disease control schemes, it is often argued that governments should use financial, incentive-based policy instruments to compensate farmers for externalities, assuming they act in rational self-interest. Our results suggest that in addition to economic motives, farmers can have intrinsic or social motives to invest in livestock disease control. Implications for the effectiveness of providing subsidy or information to motivate voluntary participation are discussed.

Keywords: *Livestock disease control*; *policy instruments*; *voluntary vaccination*; *bluetongue*; *integrated choice and latent variable model*; *preference heterogeneity*; *attitude*; *perceived norms*.

JEL classifications: *C25, D62, D91, Q18*.

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1. Introduction

Bluetongue is a vector-borne livestock disease caused by the bluetongue virus, and has been identified on all continents except Antarctica. Biting midges (*Culicoides* spp.) transmit the virus from infected to susceptible ruminants (Maclachlan, 2011). An outbreak of a vector-borne disease can have large socio-economic consequences in terms of livestock production, policy and trade in the countries or regions affected (Burrell, 2002). A large epidemic of bluetongue virus serotype 8 occurred in Europe during 2006 to 2009. Several years later, multiple outbreaks were reported in France in the autumn of 2015 (Saileau *et al.*, 2017). Re-emergence of bluetongue in Europe poses a continuous threat for livestock production. Large-scale vaccination is the most effective intervention to control the spread (e.g. Wilson and Mellor, 2009).

Livestock disease control policies have traditionally followed a command-and-control approach of regulation and enforcement, but voluntary approaches are now also being considered. During the bluetongue virus serotype 8 epidemic in 2006 to 2009, some European Union Member States adopted voluntary vaccination schemes (Wilson and Mellor, 2009). Outbreaks in France continued to be reported in 2016 and animal health authorities in the UK have been considering whether vaccination strategies should be implemented, and in what form (Bessell *et al.*, 2016; Roberts *et al.*, 2016). Voluntary approaches are more flexible in terms of legislation and can also be effective at lower costs, provided that farmers are willing to participate (Segerson, 2013).

Theoretical economic studies that take into account the endogenous nature of infection risk, predict that farmers are likely to underinvest in private disease control measures compared to a social welfare optimum because of the presence of externalities (e.g. Beach *et al.*, 2007; Rat-Aspert and Fourichon, 2010; Gramig and Horan, 2011; Zilberman *et al.*, 2012), since vaccination helps a region become disease free, while no vaccination contributes to disease transmission. Public intervention may be justified when such market failures occur. Other market failures arise from information asymmetries, resulting in moral hazard and adverse selection problems (e.g. Gramig *et al.*, 2009; Hennessy and Wolf, 2015). These studies focus on the design and use of financial, incentive-based policy instruments to compensate for externalities. The farmer's decision-making process is modelled as a 'black box', which does not consider how preferences are formed and choices are made (Ben-Akiva *et al.*, 1999; McFadden, 1999) and are limited in their ability to account for process and context in decision making, failing to account for heterogeneity in decision making among farmers. If the willingness to invest in vaccination is also driven by intrinsic and social motives, this could imply that a mix of policy instruments, rather than simply financial compensation, is needed to make voluntary approaches more effective (Barnes *et al.*, 2015; Ochieng' and Hobbs, 2016).

A complementary body of literature focuses on the identification and assessment of key factors that influence decision making on livestock disease control, using qualitative and quantitative research methods. In addition to instrumental considerations (e.g. private risks and income effects), the experiential consequences of disease control decisions are important for many farmers (Elbers *et al.*, 2010; Gethmann *et al.*, 2015; Sok *et al.*, 2015). In the economic literature, these are described as non-use or passive values (e.g. Hansson and Lagerkvist, 2015; Schreiner and Hess, 2017) or non-pecuniary benefits (Howley, 2015). Another key factor is that private decisions could be influenced by social pressures through different types of perceived norms (Jones *et al.*, 2015; Vande Velde *et al.*, 2015; Sok *et al.*, 2016b). Furthermore, it is important to account for specific perceptions about disease risk, about the safety and effectiveness of applied measures and about the trust and confidence in the disease control approach chosen by animal health authorities (e.g. Perry *et al.*, 2001; Flaten *et al.*, 2005; Heffernan *et al.*, 2008; Palmer *et al.*, 2009; Valeeva *et al.*, 2011; Schemann *et al.*, 2012; Toma *et al.*, 2013; Alarcon *et al.*, 2014; Enticott *et al.*, 2014; Maye *et al.*, 2014; Sok *et al.*, 2016a).

Several authors in the domain of economics of animal health have suggested complementing economic theory with insights from behavioural sciences to improve the understanding of livestock disease control decisions, to identify ways of motivating farmers to comply with voluntary approaches (Barnes *et al.*, 2015; Gilbert and Rushton, 2016). It would be useful to develop and test a utility model representation of farmers' behaviour that allows for heterogeneity in the motives to invest in disease control, before further studying the dynamic interactions between farmers' collective behaviour and disease epidemiology. Given the nature of disease control efforts as public goods and the presence of non-use values in decision making, a stated preference approach can assess farmers' preferences for different attributes of livestock disease control policies (Adamowicz *et al.*, 1998). In addition to instrumental attributes, such as the vaccine effectiveness or costs (Bennett and Balcombe, 2012), key factors that were previously described can help in defining other attributes that are important for policy-making.

This study has two objectives: first, to assess farmers' preferences for policy-related attributes of a bluetongue vaccination scheme; second, to improve the understanding of the factors underlying the behavioural heterogeneity in farmers' preferences for these attributes. We use a survey-based discrete choice experiment to derive farmers' marginal utilities of attributes of public voluntary bluetongue vaccination schemes. Heterogeneity in preferences for attributes is commonly modelled via unobserved random effects (McFadden and Train, 2000; Hensher and Greene, 2003) and readily observable and relatively objective characteristics. More recently, preference heterogeneity is partially modelled using latent constructs from social psychology to enhance the behavioural representation in choice models. Such models have been mainly developed in the marketing and transport literature, where they are known as the hybrid choice model or integrated choice and latent variable model (ICLV) (e.g. Ben-Akiva *et al.*, 2012; Hildebrandt *et al.*, 2012). The ICLV model offers a general econometric framework to supplement economic theory with concepts or theories from other social sciences (Walker and Ben-Akiva, 2002; Walker *et al.*, 2007). We use the ICLV approach to incorporate preferences for attributes, latent social-psychological constructs in addition to readily observable farm and farmer characteristics.

2. Framework: Integrated Choice and Latent Variable Model

The vaccination choice is formulated as a discrete choice problem, which is consistent with random utility theory and various econometric models. Vaccination schemes differ in terms of a few choice attributes. The utility derived from a vaccination scheme is the sum of the utilities derived from the choice attributes (Lancaster, 1966). Faced with alternative vaccination schemes, farmers are presumed to choose the alternative (or the option to not vaccinate) that is likely to give them the highest utility.

The standard approach in econometrics to account for heterogeneity in preferences is to include a random component using a mixed logit model specification (McFadden and Train, 2000; Hensher and Greene, 2003) and readily observable and relatively objective characteristics. In the mixed logit model, the utilities of the choice attributes are assumed to vary across farmers according to some pre-specified (usually normal) distributions and the sufficient statistics describing the distribution are estimated (for a normal distribution: the mean and the standard deviation). If the estimated standard deviations are significant, statistical unobserved heterogeneity in preferences is present. However, as there are many sources of preference heterogeneity, researchers have indicated that the underlying causes of heterogeneity need to be better understood by linking the heterogeneity to the characteristics of the decision maker (e.g. Louviere *et al.*, 2002; Rigby and Burton, 2005; Kjær and Gyrd-Hansen, 2008; Hess, 2012). In their seminal papers on the ICLV model framework, Ben-Akiva *et al.* (1999, 2002, 2012) suggest taking more account of process (steps involved in decision making) and context (factors affecting the process) to enhance the behavioural representation in choice models. They do so by including social-psychological constructs in choice models (Hess, 2012).

In the ICLV model framework, attitudes are used most frequently for modelling preference heterogeneity (Hess and Beharry-Borg, 2012; O'Neill *et al.*, 2014; Mariel *et al.*, 2015), but personality traits (Vredin Johansson *et al.*, 2006; Yangui *et al.*, 2016) and specific perceptions (Márquez *et al.*, 2014; Kassahun *et al.*, 2016) are also used. Studies have also considered the effect of the social environment on decision-making (Abou-Zeid and Ben-Akiva, 2011; Kamargianni *et al.*, 2014; Kim *et al.*, 2014; Czajkowski *et al.*, 2017).

We capture process and context by three latent constructs: attitude, the injunctive norm and the descriptive norm in relation to participation in a bluetongue vaccination scheme. These constructs are operationalised using latent constructs from the reasoned action approach (RAA) decision model from social psychology (Fishbein and Ajzen, 2010). This model not only suggests which constructs explain behaviour but also provides a method to measure them consistently. Sok *et al.* (2015, 2016b) previously applied the RAA model to the bluetongue vaccination problem. They found that attitude and social pressures (both perceived norms) best explained intention, while control considerations played only a minor role. Based on these results, only attitude, injunctive norm and descriptive norm were measured in the current survey.

Attitude is defined as 'a latent disposition or tendency to respond with some degree of favourableness or unfavourableness to a psychological object', where the latter includes behaviour (Fishbein and Ajzen, 2010, p. 76). It is the farmer's positive or negative evaluation of performing vaccination, and can be based on instrumental (e.g. risk insurance) as well as experiential beliefs (e.g. animal suffering) (Sok *et al.*, 2015, 2016a).

Injunctive norms are defined as 'perceptions concerning what should or ought to be done with respect to performing a given behaviour', while descriptive norms refer to 'perceptions that others are or are not performing the behaviour in question' (Fishbein and Ajzen, 2010, p. 131). Sok *et al.* (2015) identified the following referents of influence for the bluetongue vaccination problem: family members, the veterinarian, peers and leaders, and the buyer.

The next section presents our materials and methods, including the choice experiment design, the indicator variables and the econometric models we use to estimate the relationships. Section 4 presents our results, while section 5 provides some discussion of the results and section 6 concludes.

3. Materials and Methods

3.1. Survey

The choice experiment survey[2] measured three groups of variables: choices, indicators for the social-psychological constructs and socio-demographic characteristics. Respondents were asked to choose their preferred alternative from each of eight choice sets. Each choice set consisted of two hypothetical vaccination schemes and a no-choice option. Each vaccination scheme was defined in terms of a combination of levels for five choice attributes. Figure 1 shows an example of a choice card. Table 1 provides an overview of all attribute levels. The survey continued with statements that measured attitude and perceived norms and ended with questions about farm and farmer characteristics.

3.1.1. Choice experiment design

The Netherlands is currently free of bluetongue. A hypothetical scenario was therefore developed that described, as realistically as possible, a situation where bluetongue had been detected 100 kilometres from the premises of the respondent. Next, it was mentioned that veterinary experts estimated the probability of infection as 5 out of 10 farms during the summer of 2015. Animal health authorities were preparing a vaccination scheme in which the respondent could participate during the spring of 2015 (when the survey was sent out). Participation in the vaccination scheme would reduce the probability of infection at the farm towards nil. Instructions explaining the choice task followed the scenario description. Attributes and their levels were explained and an example of a choice card was shown.

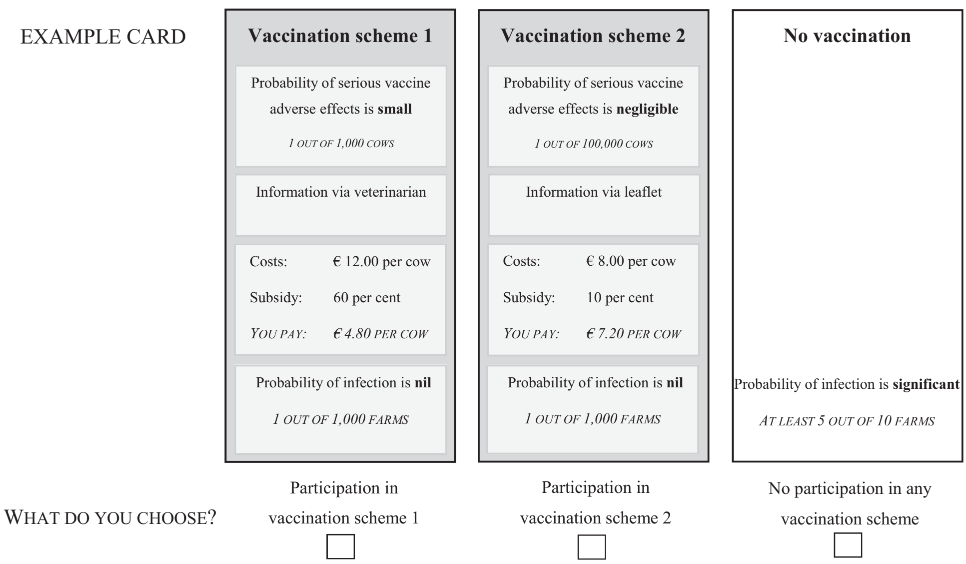

Figure 1. Example of a choice card with two hypothetical vaccination schemes and a no-choice alternative

[2]The questionnaire is available from the authors upon request.

Table 1
Details of the selected choice attributes and attribute levels of the vaccination schemes

	Choice attributes				
	1.	2.	3.	4.	5.
Description	Probability of serious adverse vaccine effects	Government comm.	Government subs.	Vaccination costs per cow	Probability of infection in the herd
Levels	Significant	No communication	No subsidy	4	Significant (ASC_no)
	Small	*Through leaflet*	*10* per cent	*8*	Nil (ASC_yes)
	Negligible	Through vet	60 per cent	12	
		Through lflt & vet			

Note: The base levels are in cursive text.

The scenario description and selection of choice attributes and their levels (see Table 1) were set by a multidisciplinary team, consisting of a veterinary epidemiologist, economists specialised in animal health and a statistician, to ensure that the choice card designed to capture farmers' perceptions and preferences would be both actionable for policy-makers and fit within a workable experimental design. The results from previous studies on the identification and assessment of key factors that influence decision-making on bluetongue vaccination were also considered (Elbers *et al.*, 2010; Sok *et al.*, 2015, 2016a).

The choice attributes 1 to 4 are policy related. The previous bluetongue vaccination scheme in the Netherlands (in 2008–10) used inactivated vaccines, which have very low probabilities of adverse effects. The attribute 'probability of serious adverse vaccine effects' was still included to reflect farmers' perceived trust and confidence in the vaccine safety and effectiveness and in the disease control approach chosen by animal health authorities. Two types of policy instruments were included as attributes: 'government information' (communication), as an informational instrument that can increase the motivation by reasoned opinions: and 'government subsidy', as an incentive-based instrument to encourage participation by lowering the net cost of vaccination. The level of subsidy can also have a signalling function, indicating the extent to which the government takes the issue seriously. The attribute 'vaccination costs per cow' was included as a price attribute. The attribute 'probability of infection in the herd' only varied between the vaccination and no-vaccination (no-choice) alternatives.

A fractional factorial main-effects experimental design resulted in 16 hypothetical vaccination schemes, from which 16 choice sets were generated by means of a cyclic design. Sixteen more choice sets were generated by permuting 'communication' levels in such a way that all possible pairs of 'communication' levels appeared in choice sets. The 32 choice sets were partitioned into four blocks. Each respondent was offered eight choice cards with three alternatives: two hypothetical vaccination schemes with varying levels on the first four attributes and an opt-out alternative, the latter representing the choice not to vaccinate.

3.1.2. Indicators representing social-psychological constructs

Farmers' attitude towards participation in a bluetongue vaccination scheme were measured using five 7-point semantic differential scales with bipolar adjectives, such as (un)satisfying and (un)important, taking into account both instrumental and experiential (non-use) aspects (see Table 3 below). Thus, the question for each scale was: 'Participation in a vaccination scheme against bluetongue is <*adjective*> for my farm'.

The injunctive norm with respect to participation in a bluetongue vaccination scheme was measured using three 7-point Likert-type scales with end points 'disagree strongly' and 'agree strongly'. The three statements were: 'People who have a lot to do with my farm expect me to participate in a vaccination scheme against bluetongue', 'People whose opinions or vision I value would approve of me participating in a vaccination scheme against bluetongue' and 'People who are close to me expect me to participate in a vaccination scheme against bluetongue'. The descriptive norm with respect to participation in a bluetongue vaccination scheme was measured using two 7-point Likert-type scales with end points 'disagree strongly' and 'agree strongly'. The statements were: 'Surrounding dairy farmers will participate in a vaccination scheme against bluetongue' and 'Dairy farmers in my social network will participate in a vaccination scheme against bluetongue'.

3.1.3. Farm and farmer characteristics

Farm characteristics were selected to capture the variation in scale and intensity with which the farm is operated, namely herd size, average milk production and the amount of pasture land utilised. Whether heifers are kept for export was the final farm characteristic measured. The farmer characteristics measured were age and level of education.

3.2. Econometric approach

Figure 2 visualises the ICLV model for the bluetongue vaccination problem as an integration of a discrete choice model and a latent variable model. The use of latent

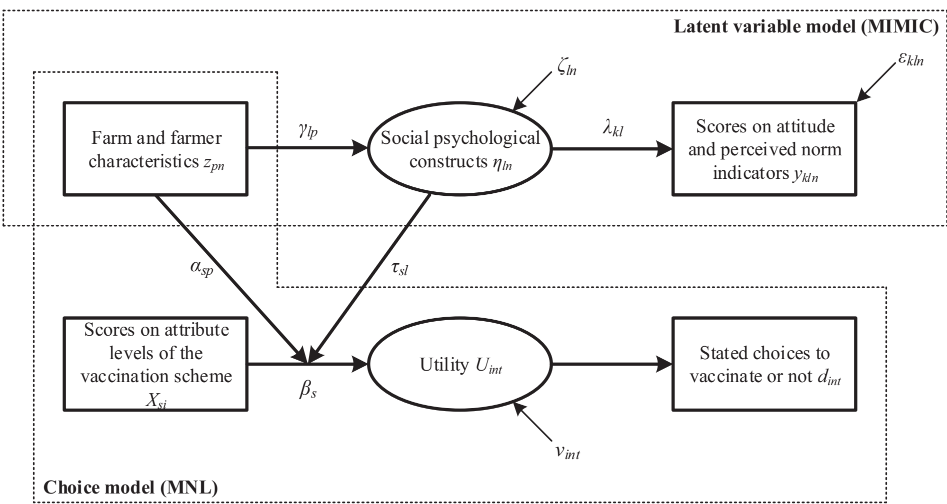

Figure 2. The integrated choice and latent variable model specification used in this paper. Squares represent observed variables and ellipses represent latent variables

variables instead of observed variables for conceptualising social-psychological constructs is advocated by, for example, Walker (2001). The latent variable model is supposed to capture some of the process and context of decision making by measuring farmers' attitude and injunctive norm and descriptive norms. These social-psychological constructs are expected to reflect part of the behavioural heterogeneity farmers have for different vaccination scheme attributes.

Various statistical approaches have been used to capture constructs in choice models (Walker, 2001). One approach is to include the indicators directly in the utility function (e.g. Onozaka *et al*., 2011). Measurement error can be introduced with this approach since the indicators are only a function of the construct and not the underlying construct itself. There is also a risk of creating endogeneity bias since it is likely that unobserved effects at the same time influence the response to choice as well as indicator questions (Ashok *et al*., 2002). Another approach is to first perform a factor analysis on the indicators, and then include the resulting construct(s) in the utility function (e.g. Greiner, 2015). In the aforementioned study no farm and farmer characteristics were used to explain preference heterogeneity. Within the ICLV model framework, it is recognised that farm and farmer characteristics can impact both on latent variables as well as on utility (see Figure 2).

Two statistical approaches result in consistent estimates for ICLV models: the sequential estimation approach (limited information, two steps) and the simultaneous estimation approach (full information, one step) (Walker, 2001). In the sequential estimation approach, a multiple indicator and multiple causes model (MIMIC) (Jöreskog and Goldberger, 1975; Diamantopoulos *et al*., 2008) is used to specify and test the relationships between farm and farmer characteristics and the attitude and perceived norms indicators (see Figure 2). A MIMIC model is a special case of structural equation modelling (SEM). The predicted conditional means (factor scores) of these constructs are saved and entered into the choice model specification. The simultaneous estimation approach estimates a MIMIC and choice model in a single step and is thus more efficient. However, the maximum likelihood procedure often suffers from convergence problems when multiple latent variables are included because of multiple integrals (e.g. Raveau *et al*., 2010; Daziano and Rizzi, 2015; Bahamonde-Birke *et al*., 2017). We therefore adopt the consistent but less efficient sequential estimation approach.[3] The models were estimated with Stata 13 (StataCorp, 2013), which provides built-in commands for estimating SEM and alternative-specific conditional logit (McFadden's choice) models. The user-written command developed by Hole (2007) was used to estimate mixed logit models.

3.2.1. Latent variable model

The MIMIC model was estimated using the two-step approach for SEM following Anderson and Gerbing (1988). The first stage consists of testing the measurement model that specifies the relations between the latent constructs (attitude, injunctive norm and descriptive norm) and their observed indicators, also known as a confirmatory factor analysis model.

[3]Efforts were made to estimate the ICLV model simultaneously using Pythonbiogeme (Bierlaire, 2016) to test whether more efficient parameter estimates could be obtained. This was unsuccessful. Models with only one latent variable were successfully estimated but indicated only small differences in standard errors compared to similar models estimated in a sequential manner.

Scores on indicators y_{kln} for latent variable l were modelled as effects of scores on their corresponding latent variables η_{ln}:

$$y_{kln} = \lambda_{kl} \cdot \eta_{ln} + \varepsilon_{kln}, \tag{1}$$

where y_{kln} is the score for decision maker n on the kth reflective indicator of latent variable η_l, ε_{kln} is the measurement error in that score and λ_{kl} are factor loadings, capturing the effect of η_l on y_{kl} (Figure 2). The measurement errors for each indicator were assumed to be normally i.i.d. and uncorrelated across indicators.

The overall model fit was assessed using the goodness-of-fit measures most commonly used in the SEM literature, along with their cut-off values for acceptance (see e.g. Hu and Bentler, 1998, 1999; Bagozzi and Yi, 2012): the root mean square error of approximation (RMSEA) ≤ 0.06, the Bentler comparative fit index (CFI) ≥ 0.95 and the standardised root mean square residual (SRMR) ≤ 0.08. The validity of the hypothesised latent constructs was also assessed.[4] Hair *et al.* (2010) describe construct validity as the extent to which a set of observed variables actually reflects the latent construct which those variables are designed to measure, requiring convergent and discriminant validity. Good convergent validity (reliability) of a specific latent construct is indicated by a high proportion of shared variance among indicators, and is usually assessed with the average variance extracted (AVE) and composite reliability (CR) statistics (Fornell and Larcker, 1981). Good discriminant validity means that a latent construct is truly distinct from other latent constructs, and is assessed by checking whether the AVE values of a latent construct exceed its correlations with other latent constructs.

Given a good fit and acceptable validity, the structural model was estimated in the second stage. In addition to equation (1), the social-psychological constructs were modelled as being partially caused by observed farm and farmer characteristics (Figure 2):

$$\eta_{ln} = \sum_{p} \gamma_{lp} \cdot z_{pn} + \zeta_{ln}, \tag{2}$$

where γ_{lp} are regression coefficients capturing the effect of the pth farm or farmer characteristic z_p on η_l. The error terms ζ_{ln} were assumed to be normally i.i.d. and allowed to correlate across latent variables. Assuming that the farm and farmer characteristics are specified as error free, the error terms represent the impact of all remaining explanatory variables on the latent variables (Diamantopoulos, 2006). Equations (1) and (2) were jointly estimated as a MIMIC model. All farm and farmer characteristics were included simultaneously in the structural model to test their effects on the latent constructs. Effects that were not significant at the 20 per cent critical level were removed one at a time in an iterative process, starting with the effect that had the lowest t-value (Diamantopoulos and Winklhofer, 2001). Scores for the latent variables included in the ICLV models were derived from the final MIMIC model.

3.2.2. Choice model

Assuming a rational cognitive process of utility maximisation, the decision maker n chooses alternative i in choice situation t in which he or she faces the set of available alternatives C_{nt} if:

[4]Although the simultaneous estimation approach has become standard in the ICLV literature, a potential danger when using this approach is that not enough attention is given to the validity of the hypothesised social-psychological constructs.

$$U_{int} > U_{jnt}; \forall j \neq i, j \in C_{nt}. \quad (3)$$

Utility U_{int} of alternative i for decision maker n in choice situation t was modelled as:

$$U_{int} = V_{in} + v_{int}, \quad (4)$$

where V_{in} is called the representative utility, which is the part of the utility that is deterministic and v_{int} is a stochastic error term that is independently Type-1 extreme-value distributed, which leads to a multinomial (MNL) model specification (McFadden, 1974).

In the case where no preference heterogeneity is considered among decision makers, the representative utility is dependent on the trade-offs made between attributes, and V_{in} is modelled as a linear specification:

$$V_{in} = \beta_s \cdot X_{si} \qquad \text{(MNL)} \quad (5)$$

where X_{si} are the attributes with level s of bluetongue vaccination scheme alternative i, and β_s are the regression coefficients that can be interpreted as marginal utilities. Preference heterogeneity among decision makers can be introduced in the model by adding a normally distributed stochastic component to the marginal utilities, which leads to a mixed logit (MXL) model specification (Hensher and Greene, 2003):

$$V_{in} = (\beta_s + \sigma_{sn}) \cdot X_{si} \qquad \text{(MXL)} \quad (6)$$

where σ_{sn} is a vector of parameters that represents the individual decision maker's deviations from the average marginal utilities, so that each decision maker now derives specific marginal utilities ($\beta_{sn} = \beta_s + \sigma_{sn}$) from the attributes. These individual deviations are assumed to be normally distributed with zero mean. Regarding the relaxation of the Independence of Irrelevant Alternatives (IIA) property in this study, correlations across alternatives and choice situations were still assumed to be zero. Preference heterogeneity can also be introduced deterministically, modelling it as a function of farm and farmer characteristics z_{pn} as well as social-psychological constructs (latent variables) η_{ln}:

$$V_{in} = \beta_s \cdot X_{si} + \left(\sum_p \alpha_{sp} \cdot z_{pn} + \sum_l \tau_{sl} \cdot \eta_{ln} \right) \cdot X_{si} \qquad \text{(MNL with interactions)} \quad (7)$$

Considering five choice attributes with a total of 12 levels (Table 1), six farm and farmer characteristics and three latent constructs (Table 2), 108 interaction effects could be considered for inclusion in the model. To keep the model parsimonious, an interaction variable selection procedure[5] was executed. The most important reason for this procedure was the expected high intercorrelations between latent constructs. High intercorrelations between attitude and perceived norms are the rule rather than the exception (Fishbein and Ajzen, 2010), and therefore the risk of multicollinearity exists if all interactions with all latent constructs are retained. Leaving latent constructs out, on the other hand, can result in omitted variable bias. Finally, an overall

[5]Interactions were tested one at a time by adding each interaction (involving all dummies coded for the particular attribute) separately to equation (5). This extensive procedure was done to avoid the issue that some effects would already be masked at this stage due to multicollinearity among the observed and latent variables. The criterion used was a likelihood-ratio test between a restricted (choice attributes only) and unrestricted (interactions added) model. Using this criterion, 28 of the 108 possible interaction variables were selected.

Table 2

Descriptive statistics of stated choices, perceived experiences of the previous Bluetongue epidemic, and scores for farm and farmer characteristics and indicators of attitude and perceived norms

		Farmers who chose out of 8 choice cards			
Variable	Unit	Always no	Sometimes yes	Always yes	Total or average
Farm(er)s	Number	20	56	135	211
Share of sample	Percentage	9.5	26.5	64.0	100.0
Past Bluetongue epidemic experiences					
Infected*	Percentage 'yes'	30.0	39.3	48.1	44.1
	Percentage 'no'	45.0	46.4	40.7	42.7
	Percentage 'don't know'	20.0	14.3	11.1	12.8
Vaccinated*	Percentage 'yes'	5.0	37.5	52.6	44.1
	Percentage 'no'	85.0	58.9	43.7	51.7
	Percentage 'don't know'	5.2	3.6	3.7	3.8
Farm and farmer characteristics					
Herd size†	Number	105	119	97	104
Milk production †	Kilograms (avg. cow)	7,582	8,655	8,616	8,529
Pasture land†	Hectares	68	49	44	47
Export of heifers	Yes = 1, No = 0	0.10	0.18	0.32	0.26
Age†	Years	52	46	48	48
Higher education	Yes = 1, No = 0	0.27	0.20	0.29	0.27
Average score on indicators					
Attitude‡	Scale 1–7	3.32	4.29	4.72	4.47
Injunctive norm‡	Scale 1–7	2.43	3.34	4.21	3.81
Descriptive norm‡	Scale 1–7	2.60	3.22	4.12	3.74

Notes: *One farmer in the group 'Always no' did not report the past Bluetongue experiences, so $N = 19$ for these two questions.
†These variables were mean-centred, before entering the choice model.
‡These variables were factorised and normalised, before entering the choice model (see latent variable model).

MNL and an overall MXL model were estimated, including all selected interaction effects.

The categorical choice attributes 1–3 were dummy coded, taking the levels in italics in Table 1 as base levels. Dummy coding was used to ensure an appropriate specification of the random components in the MXL models (see Walker *et al.*, 2007). The base level for the cost attribute was located at €8. The fifth choice attribute was also dummy coded, with the value 1 for the opt-out alternative, thereby accepting a significant probability of infection in the herd. This shows the relative utility (equivalent to an alternative-specific constant (ASC)) farmers attach to the no vaccination alternative compared to the base vaccination scheme. The base vaccination scheme was represented by the following attribute levels: 'probability of serious adverse vaccine effects' is *small*, 'government communication' *through leaflet*, 'government subsidy' at *10 per cent* and the 'vaccination costs per cow' at *€8*.

3.3. Sample

The sample consisted of 1,500 randomly selected Dutch dairy farms drawn from the National Cattle Identification and Registration Database. The farms selected for a previous survey on bluetongue conducted in 2014 were first removed from this database before the sample was drawn (see e.g. Sok *et al*., 2015). The selected farms were randomly subdivided into four groups. All of these groups received two different blocks in an ascending or descending order of choice cards. Each farmer in the sample was sent a paper copy of the survey along with an accompanying letter and a pre-paid return envelope. Farmers were offered two possibilities to fill in the questionnaire, using the paper copy or via a web page. By filling in their e-mail address, respondents had a 10 per cent chance of winning a gift coupon worth €25.

The survey was sent out in the last week of April 2015. A reminder was sent three weeks after the survey was sent out, followed by another reminder three weeks later. A total of 280 farmers responded, a response rate of almost 19 per cent. This was low compared to the response rate of almost 28 per cent for the survey on bluetongue vaccination conducted in 2014 (e.g. Sok *et al*., 2015). The difference in response rates is most likely because of the timing of the surveys. The first survey was held in January/February while the second was held in April/May, when farmers are more likely to be busy with field activities.

Observations with missing values were excluded from the statistical analysis, resulting in an effective sample size of 211 respondents. Most of the excluded surveys missed the whole set of indicators or farm and farmer characteristics, or both. For surveys that missed only a few values, the most frequently missing variables were average milk production and education level (46 responses were missing both variables).

Table 2 presents descriptive statistics of the stated choices, perceived experiences during the previous bluetongue epidemic, and the scores for farm and farmer characteristics and indicators for attitude and perceived norms. The first row shows the distribution of respondents' vaccination choices. The next two rows show the perceived experiences during the previous bluetongue epidemic. The majority of the farmers always chose a vaccination alternative (64 per cent) while about one tenth never chose a vaccination alternative. Farmers who perceived their herd to be infected or perceived they vaccinated during the previous epidemic more often chose a vaccination alternative from the eight choice cards. Approximately 44 per cent of the farmers reported that they had vaccinated in the previous epidemic, indicating that the sample also captured farmers without previous vaccination experience. The sample representativeness was further checked by comparing the values for farm and farmer characteristics with the values measured by other sources. According to the Dutch Farm Accountancy Data Network, the average dairy farm in the Netherlands had 103 dairy cows and 55 hectares of land in 2015 (LEI, 2016). According to statistics from the Cattle Improvement Co-operative, average milk production (305 days) of dairy cows in the Netherlands was 8,573 kilograms in 2015 (CRV, 2015). A similar survey among dairy farmers executed in 2014 (Sok *et al*., 2016a) reported similar results for farmer characteristics (age and education level).

4. Results

4.1. Latent variable model results

In the first step, the measurement model was tested to assess the overall model fit and the validity of the latent constructs (equation (1)). Values of the indices measuring the

Table 3
Estimation results from the MIMIC model

	Attitude		Injunctive norm		Descriptive norm	
	Coef.	Std. Err.	Coef.	Std. err.	Coef.	Std. err.
Structural model						
Herd size	0.11	(0.08)	0.18	(0.08)**		
Milk production	0.08	(0.06)				
Pasture land	–0.36	(0.08)***	–0.34	(0.09)***	–0.18	(0.07)***
Export of heifers	0.19	(0.07)***	0.18	(0.07)***	0.23	(0.07)***
Age					–0.11	(0.06)*
Explained variance (R^2)	0.14		0.10		0.10	
Measurement model						
Unsatisfying-satisfying scale	0.78	(0.03)***				
Unimportant-important scale	0.86	(0.02)***				
Bad-good scale	0.89	(0.02)***				
Useful-useless scale	–0.83	(0.02)***				
Disturbing-reassuring scale	0.79	(0.03)***				
People who have to do a lot with my farm [. . .]			0.79	(0.04)***		
People whose opinions or vision I value [. . .]			0.54	(0.06)***		
People who are close to me [. . .]			0.87	(0.03)***		
Surrounding dairy farmers [. . .]					0.80	(0.04)***
Dairy farmers in my social network [. . .]					0.89	(0.04)***
Disturbance term intercorrelations						
Attitude	1					
Injunctive norm	0.59	(0.06)***	1			
Descriptive norm	0.58	(0.06)***	0.64	(0.06)***	1	

***Notes*:** N = 211. *, ** and *** indicate significance level at 0.10, 0.05 and 0.01, respectively.

overall model fit were all below the criteria for acceptance (χ^2/df = 1.42 with P-value 0.06, RMSEA = 0.04, CFI = 0.99 and SRMR = 0.03). The values of the AVE (0.69, 0.56 and 0.72 for attitude, injunctive norm and descriptive norm, respectively) and CR (0.80, 0.78 and 0.84) statistics further confirmed good validity of the hypothesised latent constructs. Therefore the proposed measurement model specification was accepted and the structural model was estimated. The final MIMIC model with the selected farm and farmer characteristics showed good model fit (χ^2/df = 1.33 with P-value 0.03, RMSEA = 0.04, CFI = 0.98 and SRMR = 0.04). Table 3 shows the results of this estimation. Herd size, milk production level and pasture land availability are associated with variability in attitude. These associations suggest that farmers who have more intensive dairy farms are more favourable towards vaccination. Some of these associations also apply to variability in perceived norms. Another clear pattern is that farmers who export heifers have a more positive attitude and higher injunctive and descriptive norms. Finally, older farmers scored lower on descriptive norm.

Farm and farmer characteristics explained only a little of the variance in each latent construct. Much of the unexplained variance, captured by the disturbance terms, is shared between latent constructs, as shown by the disturbance term correlations (Table 3).

4.2. Choice model results

Table 4 reports the final model estimations after the selection procedure for the interaction variables. All models fitted the data well: the McFadden's pseudo R^2 measures were within or beyond the range for a good model fit (0.2–0.4) (Hensher *et al.*, 2005). The MXL models outperformed the MNL models, reflected in the values for the pseudo R^2, Akaike information criteria (AIC) and the Bayesian information criteria (BIC).[6]

Starting with the MNL and MXL models without interactions, positive marginal utilities imply an increase in utility relative to the base level, making participation in a vaccination scheme more probable. All marginal utilities had the expected sign, e.g. the marginal utility of vaccination costs was negative, meaning that higher cost decreases utility and the likelihood of participation in a vaccination scheme. Compared to the vaccination scheme with base levels, the likelihood of participation increased with the probability of serious adverse vaccine effects being negligible, government communication provided via veterinarians and government subsidy of 60 per cent. The likelihood of participation decreased with vaccination costs and the probability of serious adverse vaccine effects being significant. The utility of no government subsidy was not significantly different from the base level of 10 per cent, suggesting that the level of subsidy has a categorical rather than a marginal effect on preferences. Something similar held for government communication: the utility of no communication was not significantly different from the base level of providing information through leaflets. Finally, the significant negative beta of the no-choice or opt-out alternative indicated that if farmers did not choose any vaccination alternative, their utility significantly reduced. This suggests that many farmers are willing to participate in a bluetongue vaccination scheme to minimise the probability of infection in their herd.

The estimated sigma's in the MXL model show the choice attributes that have preference heterogeneity. This was the case for all choice attributes except government communication. In the MNL and MXL models with interactions, most interaction effects related to the probability of infection in the herd (ASC) and the probability of serious adverse vaccine effects.

Results from the MIMIC model previously suggested that higher scores on the latent constructs are relatively weakly associated with larger-scale farms, more intensive farms and farms that keep heifers for export. Part of these effects are thus absorbed in the predicted conditional means of these latent constructs. However, the underlying farm characteristics still interacted significantly with some choice attributes, in particular with the marginal utility of the no-vaccination option. Thus,

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[6]Both mixed models were also estimated without any identification constraints on the standard deviations of the random marginal utility coefficients. Results showed that our identification constraints (fixing the standard deviations of the marginal utilities for the base levels to 0), closely (for the model without interactions) or perfectly (for the model with interactions) coincided with the recommendation by Walker *et al.* (2007) to constrain the smallest standard deviations from the unconstrained models to 0 for identification.

Table 4
Estimation results from the choice models after selection of the interaction variables

		MNL	MNL with interactions	MXL†		MXL with interactions†	
Main effects		β	β	β	σ	β	σ
Adverse effects probability	Significant	−1.77 (0.10)***	−1.78 (0.12)***	−6.68 (0.98)***	5.37 (0.81)***	−6.48 (1.03)***	4.64 (0.67)***
(base: Small)	Negligible	0.41 (0.09)***	0.50 (0.11)***	1.69 (0.32)***	2.39 (0.44)***	1.69 (0.37)***	2.62 (0.56)***
Government communication	No comm.	0.16 (0.12)	0.09 (0.13)	0.03 (0.28)	0.31 (0.59)	−0.14 (0.29)	0.35 (0.59)
(base: Through	Through vet	0.30 (0.12)**	0.25 (0.13)**	0.72 (0.27)***	0.03 (0.59)	0.65 (0.29)**	0.71 (0.46)
leaflet)	Through lflt & vet	0.13 (0.11)	0.09 (0.12)	0.10 (0.26)	0.02 (0.49)	0.06 (0.27)	3 (0.56) 0.1
Government subsidy	No subs.	−0.09 (0.08)	−0.10 (0.09)	−0.18 (0.20)	1.17 (0.37)***	−0.12 (0.21)	1.10 (0.41)***
(base: 10 per cent)	60 per cent	0.83 (0.11)***	0.91 (0.12)***	2.51 (0.39)***	1.45 (0.41)***	2.74 (0.44)***	1.46 (0.45)***
Vaccination costs		−0.14 (0.01)***	−0.16 (0.02)***	−0.54 (0.08)***	0.33 (0.06)***	−0.58 (0.09)***	0.31 (0.07)***
Infection probability	ASC_no	−0.62 (0.11)***	−0.83 (0.15)***	−4.96 (0.99)***	9.29 (1.61)***	−3.80 (0.97)***	6.95 (1.09)***
Interaction effects			α or τ			α or τ	
Herd size‡	×ASC_no		0.06 (0.02)***			0.21 (0.11)*	
Milk production‡	×ASC_no		−0.27 (0.07)***			−0.85 (0.55)	
Pasture land‡	×Significant		−0.19 (0.06)***			−0.55 (0.23)**	
	×Negligible		0.05 (0.03)			0.20 (0.12)*	
	×ASC_no		−0.01 (0.04)			0.02 (0.24)	
Export of heifers	×ASC_no		−0.56 (0.21)***			−2.33 (1.80)	
Age‡	×No subs.		−0.16 (0.09)*			−0.42 (0.21)**	
	×60 per cent		−0.34 (0.11)***			−0.90 (0.30)***	
	×Vaccination costs		0.02 (0.01)*			0.10 (0.05)**	
	×ASC_no		−0.11 (0.09)			−0.90 (0.65)	

Table 4
(*Continued*)

		MNL	MNL with interactions	MXL[†]	MXL with interactions[†]
Education	×Significant		−0.56 (0.23)**		−1.43 (1.01)
	×Negligible		0.06 (0.22)		0.48 (0.64)
Attitude	×No comm.		0.08 (0.14)		0.61 (0.36)*
	×Through vet		0.30 (0.15)**		0.87 (0.37)**
	×Through lflt & vet		−0.14 (0.14)		−0.19 (0.31)
	×ASC_no		−0.93 (0.15)***		−3.03 (1.06)***
Injunctive norm	×No subs.		−0.07 (0.10)		−0.32 (0.23)
	×60 per cent		−0.21 (0.12)*		−0.69 (0.32)**
	×ASC_no		−0.51 (0.14)***		−2.02 (1.05)*
Descriptive norm	×Significant		−0.12 (0.11)		−0.53 (0.50)
	×Negligible		0.18 (0.11)*		0.73 (0.31)**
	×ASC_no		−0.19 (0.13)		−0.87 (0.99)
Model fit statistics					
Parameters		9	32	18	41
L0 (with ASC only)		−1,771	−1,771	−1,407	−1,407
LL		−1,395	−1,134	−842	−774
McFadden's pseudo-R^2		0.21	0.36	0.40	0.45
AIC/N		1.67	1.39	1.02	0.97
BIC/N		1.71	1.51	1.09	1.13

Notes: $N_{\text{choice cards}}$ = 1,680, $N_{\text{respondents}}$ = 211. Standard deviation in parentheses. *, ** and *** indicate significance level at 0.10, 0.05 and 0.01, respectively.

[†]The simulated maximum likelihood was based on 5,000 Halton draws (Hole, 2007).

[‡]All observations were divided by 10 and 1,000 respectively, for scaling reasons.

farmers operating larger-scale and/or more intensive dairy farms are more likely to vaccinate, as are farmers who export heifers.

Farmers' age and education level were not influential in the MIMIC model in explaining variability in the latent constructs. In the choice models with interactions, age had a moderating effect on monetary attributes: the level of government subsidy and vaccination costs. Older farmers appear willing to pay more for the vaccine given that they derive less utility from the government subsidy of 60 per cent and less disutility from higher vaccination costs. Farmers with higher education degrees are less likely to vaccinate if the probability of serious adverse vaccine effects is significant.[7]

Attitude and injunctive norm interacted negatively with the ASC – the utility of the no-choice or opt-out alternative. Thus, the more favourable the farmer's attitude towards vaccination and the more social pressure perceived by the farmer, the more likely the farmer is to vaccinate. Attitude also interacted positively with government communication provided via veterinarians, while injunctive norm interacted negatively with government subsidy of 60 per cent. Descriptive norm interacted positively with the probability of serious adverse vaccine effects being negligible.

5. Summary and Discussion

In their utility trade-offs between choice attributes, farmers perceived the probability of serious adverse vaccine effects as one of the most important attributes. Preference heterogeneity for this attribute was retrieved via interactions with pasture land, education level and descriptive norm. The first two interaction effects might show that farmers' views on disease resistance (or resilience) and its consequences for the intensity with which a farm should be operated are linked with how they perceive the likelihood and impact of adverse vaccine effects. This links to results from the latent variable model, where it was found that farmers who have more (less) intensive dairy farms are more (less) favourable towards vaccination.

The importance of perceived trust and confidence in vaccine safety and effectiveness and in the disease control approach chosen by animal health authorities is highlighted by two interaction effects in particular. Descriptive norm interacted positively with the probability of serious adverse vaccine effects being negligible. This suggests that farmers are more likely to vaccinate if they perceive that others in their social network vaccinate (presumably without experiencing adverse effects). Furthermore, attitude interacted positively with government communication provided via veterinarians. Attitude change, communication and persuasion are closely related. Source and message characteristics (e.g. credibility) together with the internal motivation and ability to process information determine whether attitude change is induced (e.g. Petty and Cacioppo, 1996; Blackstock *et al.*, 2010). Sok *et al.* (2015) showed for the same research problem that the government representative was one of the least important referents, while the veterinarian and peer farmers were more important referents. Frewer *et al.* (1996) show that for food-related risks, government representatives are among the least trusted sources of risk information.

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[7]An interaction effect between education level and the ASC was highly significant in both the MNL and MXL models. However, the interaction variable selection procedure revealed that this correlation was spurious. Since dummy coding was used, the effect captured was the significant interaction between education level and the probability of serious adverse vaccine effects being small (see Bech and Gyrd-Hansen, 2005 for an explanation).

Another important finding relates to the provision of a government subsidy as a means to lower the vaccination costs for the farmer. Injunctive norm interacted negatively with government subsidy of 60 per cent. Subsidisation is an incentive-based policy instrument and functions, just as certain norms, as an external motivating factor. As such, subsidisation and social pressures via injunctive norms are both external motivating factors. Our results indicate that these factors might function as substitutes for at least some farmers.

This 'crowding out' effect has been reviewed by Bowles and Polanía-Reyes (2012, p. 368), who indicate that 'this may occur when incentives adversely affect individuals' altruism, ethical norms, intrinsic motives to serve the public, and other social preferences'. One of the suggested underlying mechanisms for the substitution effect is that subsidies can negatively affect one's sense of autonomy (and not the capacity) over the behaviour, resulting in resistance to rather than compliance with the policy.

The interactions found between farm characteristics and the ASC reveal some clear economic motives for farmers to prefer vaccination to no vaccination. Herd vaccination is often used as an insurance against the production risk from disease infection, and also guarantees that heifers can be continuously exported irrespective of the status of the epidemic (Sok *et al*., 2014). However, the interactions found between social-psychological constructs and the ASC suggest that perceived social pressures also induce vaccination behaviour as well just as the experiential components of attitude (e.g. animal welfare considerations). This suggests that in addition to economic motives, farmers can have social and intrinsic motives to invest in disease control.

This study brings together different perspectives from economics and social psychology[8] using the flexible structure of the ICLV model framework. Compared to the MNL, the social-psychological constructs explain a considerable part of the preference heterogeneity in the ASC, resulting in better model fit statistics. Compared to the MXL model with preference heterogeneity modelled randomly, the social-psychological constructs provide behavioural explanations for the diverse preferences underlying farmers' choices to vaccinate against bluetongue. In particular, farmers' attitude provided a sound behavioural interpretation of why vaccination is preferred to no vaccination. Attitude has also been used to explain status quo effects in choice experiments (Meyerhoff and Liebe, 2009). Other latent constructs that could be relevant for modelling preference heterogeneity in livestock disease control decisions are anticipated emotions, such as guilt or regret (Onwezen *et al*., 2013), or dimensions of personal norms (Thøgersen, 2006). In this respect, choice models are emerging that are based on minimising anticipated random regret rather than on maximising random utility (Thiene *et al*., 2012; Hensher *et al*., 2013; Chorus, 2015).

6. Conclusions and Policy Implications

Results of this study suggest that, in the presence of a bluetongue outbreak, many dairy farmers in the Netherlands are willing to participate in a vaccination scheme to minimise the probability of herd infection. Farmers have economic, intrinsic or social motives to invest in livestock disease control. The likelihood of participation can be increased with providing information and subsidies. However, the efficacy of these

[8]Some of the axioms underlying the standard economic model could have been violated with the inclusion of social-psychological constructs, for a discussion see Ben-Akiva *et al*. (1999).

policy instruments to motivate farmers to vaccinate is heterogeneous and not necessarily positive for each farmer. This study has two implications for the design of policy instruments to increase the effectiveness of voluntary approaches to livestock disease control.

The first policy implication relates to the provision of subsidies. In designing livestock disease control schemes, it is often argued that governments should use financial, incentive-based policy instruments to compensate farmers for externalities, assuming they act in rational self-interest. The results of this study suggest that farmers can have private economic motives (incentives) to participate in a vaccination scheme, such as to insure the production risk from disease infection and to maintain the export of heifers. This suggests that a government subsidy might not be necessary for each farmer to guarantee a positive net benefit from vaccination. Results further suggest that the relationship between the level of subsidy and the likelihood of participation in voluntary vaccination schemes is not necessarily positive. A crowding-out effect was found between injunctive norm and government subsidy. The crowding out of intrinsic and social motives could be minimised by explaining to farmers what the meaning is of providing subsidy and where the financial sources come from. The level of subsidy and the manner in which compensation and reimbursement is offered can have a signalling function, indicating the extent to which the animal health authorities take the issue seriously.

The second implication relates to the provision of information. Perceived trust and confidence in the vaccine safety and effectiveness and in the government approach, which were reflected in preferences for the attributes 'probability of serious adverse vaccine effects' and 'government communication', were conditional on farmers' attitude and descriptive norm towards participation in a vaccination scheme. Information about the vaccine and the way in which animal health authorities plan to co-ordinate the vaccination strategy is best provided via communication channels that are perceived as credible and trustworthy. Farmers are more likely to vaccinate if they perceive that others in their social network perform vaccination without experiencing adverse effects.

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[Correction added on 06 December 2017, after first Online publication: Supporting Information has been included by mistake and has been removed in this current version]

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