CHAPTER 5

MEASURING SUBJECTIVE PROBABILITIES OF CONTAGIOUS DISEASE OUTBREAKS USING CONJOINT ANALYSIS

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Summary

More than two-thirds of the Dutch annual meat production is exported. Thus, the Netherlands is very sensitive to export bans as a result of outbreaks of contagious animal diseases. Stochastic simulation models could provide important tools for decision making on disease eradication and prevention. However, underlying data to base such models upon are scarce. Conjoint analysis is a widely used technique in marketing research to obtain data with respect to consumer preferences. In this paper an experiment is described which evaluates the possible application of conjoint analysis as a subjective probability generating technique in the field of disease control. Although the results presented in this paper are preliminary, it could be concluded that, when historical and/or experimental data are scarce, conjoint analysis provides a useful tool for obtaining additional information, such as subjective probabilities, to be used in constructing models.

1 Introduction

In 1994 the Dutch export of live animals and animal products represented a value of more than 4.5 billion US dollars (PVE, 1995). More than two-thirds of the annual meat production was exported. Consequently, export bans can be disastrous for the Dutch livestock industry. Outbreaks of diseases that are on list 'A' of the Office International des Epizooties (OIE) can cause such bans and these diseases, therefore, are greatly feared in the Netherlands and in all other meat-exporting countries. The most important List A diseases are: Foot-and-Mouth Disease (FMD), Swine Vesicular Disease (SVD), Classical Swine Fever (CSF), African Swine Fever (ASF), Newcastle Disease (ND) and Avian Influenza (AI). FMD affect swine and cattle, SVD, ASF and CSF affect only swine, ND and AI are contagious poultry diseases.

In the Netherlands, the probability of occurrence of these diseases is generally rather low. However, the consequences can be extremely serious if an outbreak does occur. Berentsen *et al.* (1990) estimated total losses from an outbreak of FMD in the Netherlands, including prevention and eradication costs, to be between 60 million and 7 billion US dollars, depending on location of the outbreak (livestock density of the affected region) and control strategy applied. The large range of this outcome indicates that policy decisions concerning prevention and eradication may have a large impact.

To aid policymakers in the area of disease prevention and eradication, a simulation model will be developed which should be flexible enough to analyse the effects of different strategies. It would be ideal to base such a model on historical and/or experimental data. But history shows that outbreaks occur irregularly and differ in magnitude, making it very difficult to derive general properties and predictive values. Furthermore, in 1992 the European Union decided to cease preventive vaccination against almost all List A diseases. Thus, outbreaks dated before 1992 occurred in a vaccinated and more or less protected population, while the Netherlands and the other EU countries are now dealing with an unvaccinated and thus highly susceptible livestock population. Experimental data are scarce as well. However, decisions on eradication and prevention programs have to be made regardless, and hence considerable effort must be put into obtaining reliable estimates and assumptions for the simulation model.

These assumptions and estimates can be derived by consulting knowledgeable people working in the fields concerned. The general issue is then how to obtain reliable and quantitative information. If there is no 'golden standard' available to judge reliability, one should as least aim at consistent quantitative information, which mirrors the opinions of the people consulted as closely as possible.

There are several techniques available to deal with this situation, ranging from very open in-depth interviews to strictly organized experiments. This study focused on the use of the so-called 'conjoint analysis' technique. Conjoint analysis is a questionnaire technique, well known and widely used in marketing research to estimate the impact of selected product characteristics on consumer preferences for products (Cattin and Wittink, 1982). According to Fishbein (1963), a product or an event can be evaluated as a composition of attributes or characteristics. The importance of each attribute is determined by the person who examines the object. Conjoint analysis enables the quantification of the relative importance, or in other words the subjective probability, of these attributes. The traditional approach of conjoint analysis is called 'full profile' and confronts the respondents with all attributes at the same time. Green and Srinivasan (1990) argue that the full profile method of conjoint analysis works very well if there are only a few (about six) attributes. If the number of attributes gets larger, the full profile approach causes information overload for the respondents and will thus result in less reliable estimates. Adaptive Conjoint Analysis (ACA) is a modified conjoint analysis approach, PC-based and especially designed for large numbers of attributes. With this approach the respondent is never asked to evaluate more than two or three attributes at a time.

For this study, both techniques were used to elicit the opinion of knowledgeable people on risk factors which can be responsible for virus introduction into the Netherlands. A number of 7 risk factors (attributes) were considered, thus creating a good situation to compare both the full profile and the ACA method. Because no 'golden standard' was available, comparison was based on behaviour of the respondents only, *i.e.*, consistency of respondents' answers and predictive value of both techniques.

2 Conjoint analysis

General

Conjoint analysis is a technique that enables quantification of the relative importance of attributes of a product or event in relation to the final preference of a subject for that particular product or event. The method was developed in the 1960s and was rooted in traditional experimentation techniques (Krantz, 1964; Luce and Tukey, 1964; Krantz and

Tversky, 1971). Basic assumptions of conjoint analysis are: (1) a product can be described according to levels of a set of attributes, and (2) the consumer's overall judgement with respect to that product is based on these attribute levels (Steenkamp, 1987).

Conjoint analysis is a so-called 'decompositional' method. Respondents are asked to rank or give a score for combinations of attributes. Using statistical analysis, the importance of each attribute can be estimated. These 'importancies' are termed 'part-worth scores' and indicate the influence of each attribute on the respondent's preference for a particular combination.

Conjoint analysis may look like a rather complicated and indirect method to reveal systematic components that underlie people's evaluations of objects. It is also possible to use a compositional method, such as direct questioning. Compositional methods ask respondents to assess values for attributes, and use these values to build up preferences for attribute bundles or profiles (Huber, 1974). These methods, also referred to as self-explicated methods, have speed and simplicity as their main advantages. However, there are also some problems, the major one being lack of realism. It is difficult for respondents to provide a non-biased score for one particular attribute, other things being equal. The decompositional methods provide the respondent with a more realistic situation, because attributes are evaluated as combinations (as is the case in the 'real world'). Besides, many researchers have compared the predictive performance of the conjoint method with the self-explicated approach and in most studies the conjoint techniques outperform the latter (Huber *et al.*, 1993; Green *et al.*, 1983). A further advantage of conjoint analysis is that the technique provides information on the consistency of answers given by the respondents.

Full profile

The traditional way of performing conjoint analysis is called 'full profile'. If using the full profile method, respondents are asked to rank or give a score for a number of profiles, where a profile stands for a specific combination of attributes. A typical example of full profile conjoint analysis may be performed by order of a car company, planning to develop a new car. In selecting a car, important attributes may be: colour, price, make, maximum speed, size *etc.* In this case, potential buyers will be shown a number of small cards, each presenting a different car. On those cards, the car is described as a combination of attributes (speed, make *etc.*), a profile. The respondent is asked to rank or give a score for each card. Statistical regression techniques are then used to derive the part-worth scores for all attributes. The customary approach to conjoint analysis is disaggregate. That is, each respondent is modelled separately. The model can be a simple additive one, but it is also possible to include interactions between attributes.

Most information can be derived when all possible profiles (a complete factorial design) are evaluated. However, in most cases this would be impractical (*e.g.*, when using seven attributes, each at two levels, a complete design would mean that respondents should evaluate a number of 2^7 or 128 profiles!). The number of profiles can be reduced, with only minimal loss of accuracy, by using a fractional factorial design. Addelman (1962, 1963) designed a number of 'basic plans' which can be used for construction of profiles. His schemes can be used for additive models ('main effect design') as well as for models that include interactions ('compromise design').

Adaptive Conjoint Analysis

Adaptive Conjoint Analysis (ACA) is a PC-based system for conjoint analysis. The term 'adaptive' refers to the fact that the interview is interactive and questions are customized for each respondent. ACA is a combination of self-explicated and conjoint techniques and belongs to the group of 'hybrid conjoint models'. Hybrid conjoint modelling combines the speed and simplicity of the self-explicated approach with the realism and generality of traditional conjoint analysis. Individual differences are retained while respondent evaluation time is reduced (Steenkamp *et al.*, 1986).

The ACA-system first screens all attributes and levels to discover which attributes are most important to the respondent. In this stage, preliminary estimates of the respondent's utilities for the attributes are made. In the second stage 'trade-off' questions are asked, based on the attributes that are important to the respondent. The questions asked in this stage are based on the information obtained in the first stage. The answers are used to refine the utility estimates, and choose further questions most likely to provide additional precision in the utility estimation. Finally some 'calibrating questions' are asked. These questions are similar to the full profile questions, the respondent is asked to indicate his/her level of interest for a certain combination of attributes (Johnson, 1987). The 'adaptive' nature of the interview enables the researcher to cover larger numbers of attributes with a relatively small number of questions.

3 Experimental design

General

To minimize the influence of social and/or political connections among participants, the experiment was structured in the form of three full evening's workshops, during which participants were asked to complete a computerized questionnaire individually. Both conjoint techniques were incorporated into this questionnaire. The program was designed to be self-explanatory in order to minimize interaction of the participants with either one another or the workshop organizers. The program included a full profile as well as an ACA task. Participants were randomly assigned to a certain task order, in such a way that about half of them started with ACA and the other half with full profile.

The aim of the workshops was to invite all people thought to be knowledgeable about, or even experts on one of the six diseases under study (FMD, SVD, CSF, ASF, ND, and AI). Fifty people were invited to join either one of the workshops. Participants were not expected to be knowledgeable about more than one or two diseases. They were given the opportunity to choose the disease about which they felt themselves most knowledgeable. Only questions for that disease were asked.

To illustrate the design and the results of the experiments, Classical Swine Fever (CSF) will be described in detail. The other diseases were dealt with in a similar way.

Questionnaire

Introduction of virus from any country into the Netherlands takes place by the so-called 'risk factors'. The literature and earlier in-depth interviews with experts have produced the following list of risk factors concerning CSF:

1. import of livestock,
2. import of animal products,
3. feeding of import swill (airports, harbours),
4. tourists,
5. returning livestock trucks,
6. wildlife, and
7. air currents (airborne transmission).

The Netherlands has relations with almost all European countries, thus in principle all countries can be responsible for transferring CSF-virus to the Netherlands (if an outbreak occurs in one of these countries). To incorporate country differences, while keeping the whole exercise of controllable size, the countries were grouped into the following five clusters:

1. cluster 1: Belgium, Germany, Luxembourg;
2. cluster 2: Greece, Italy, Portugal, Spain;
3. cluster 3: Austria, France, Switzerland;
4. cluster 4: Eastern Europe; and
5. cluster 5: Great Britain, Ireland, Scandinavia.

In this study conjoint analysis was used to derive the subjective probability of each of these risk factors with respect to each of these clusters. The introduction of virus into the Netherlands was seen as the 'event', the risk factors were the 'attributes'. Each risk factor could be either present or not present (two levels).

The full profile approach, using the Addelman schemes, resulted in eight profiles. Three randomly chosen profiles were added as 'holdouts', which were used to check the fit of the model (regression coefficients are based on the first eight profiles only). These holdouts were also used to gauge the respondents' consistency in answering the questions. The participants were presented with the profiles on their computer screen (one profile at a time) and asked to give a score (ranging from 0 to 100) for each profile. These scores were evaluated with the following model:

$$score = c + \beta_1 x_1 + \ldots\ldots + \beta_7 x_7 \qquad (1)$$

In this simple additive model, *score* is the risk score given by the respondent, c is a constant, β_i are the estimated coefficients belonging to the risk factors, and x_i are the risk factors (with values 1 = present and 0 = not present). Based on the model, the method estimates the subjective probability of each risk factor (all factors add up to 1.00 or 100%).

The ACA-system produces utility estimates for each attribute level, which are a combination of the information obtained in the several stages of the method (for more details, see Johnson, 1993). These utilities can be used to calculate the subjective probability of each risk factor.

To evaluate the predictive value of both conjoint techniques, a 'choice task' was incorporated into the questionnaire. For this task, participants were presented with three situations at a time and asked to indicate the situation they thought to be the most risky. They were also asked to indicate the least risky situation. A situation was presented as a combination of selected attributes (only three or four). Figure 1 shows an example of this choice task. Based on this choice task, so-called 'hit rates' can be calculated (among others, Huber *et al.*, 1993). For this calculation, the respondent's choice, as presented by the choice task, is compared with the estimated choice based on either the ACA or the full profile method. A higher hit rate indicates a higher predictive performance. Another measure for the predictive performance is the 'share of first choice', based on Huber *et al.* (1993). This measure indicates which percentage of the respondents choose a certain situation as the most risky one.

SITUATION 1	SITUATION 2	SITUATION 3
import of livestock	tourists	returning livestock trucks
feeding of import swill	returning livestock trucks	import animal products
tourists	import of livestock	feeding import swill
	WHICH IS THE MOST RISKY SITUATION?	1
	WHICH IS THE LEAST RISKY SITUATION?	---

Figure 1. Structure of the choice task

4 Results

In this paragraph only an illustrative selection of preliminary results is presented. Further analyses are being conducted.

All invited people responded positively to the invitation and 43 of them were able to join the workshops, which is a response rate of 86%.

The consistency in answers of the participants can be gauged in several ways. A common way when working with full profile (FP) is to make use of the holdout profiles. Consistency is measured by the correlation between the values for the holdouts as given by the respondents and the values for these holdouts as estimated by the model. Also ACA enables a kind of a consistency check: the program provides the user with the correlation between values for the calibration questions as given by the respondents, and these values estimated according to the calculated utilities. For both methods more than 85% of the respondents showed correlations larger than 0.8.

Table 1 presents the subjective probability for the risk factors concerning CSF, for all country clusters, according to both full profile and ACA. These results are based on the answers of consistent participants only. To reduce the influence of extreme answers on the aggregated results, an *M*-estimator or generalized maximum likelihood estimator (Tukey's) was used (Hoaglin *et al.*, 1982). An *M*-estimator assigns weights to the responses. These weights decrease as distance from the centre of the distribution increases. Thereafter the *M*-estimators were rescaled to 100%. Risk factors 'wildlife' and 'air' are only relevant and considered for cluster 1 (surrounding countries of the Netherlands).

Table 1 shows that, according to both methods, 'import of livestock' is the most important risk factor, followed by 'swill' and 'returning trucks'. No large differences can be observed between clusters. ACA and full profile both result in the same ranking of risk factors; however, full profile seems to result in more extreme probabilities (higher percentages for the most important factors, lower percentages for less important factors).

Table 1. Subjective probability (%) of CSF risk factors, results FP and ACA respectively

Risk factor	Cluster									
	1		2		3		4		5	
	FP	ACA	FP	ACA	FP	ACA	FP	ACA	FP	ACA
Livestock	56.0	39.5	55.6	44.7	58.4	49.0	60.3	50.4	59.4	51.6
Animal products	8.1	8.1	7.9	9.3	9.1	7.5	8.6	7.3	6.2	9.2
Swill	13.2	16.1	17.4	19.4	14.5	18.0	13.2	18.9	15.7	19.5
Tourists	4.4	4.5	3.6	4.7	3.3	5.9	4.8	4.9	5.9	6.6
Returning trucks	10.9	21.3	15.5	21.9	14.7	19.6	13.1	19.1	12.8	13.1
Wildlife	3.7	4.5	----	----	----	----	----	----	----	----
Air	3.7	6.0	----	----	----	----	----	----	----	----
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The choice task formed the basis of several comparison evaluations. Both conjoint methods resulted in subjective probabilities for the risk factors, separately calculated for each respondent. Using these values, the expected outcome of the choice task was calculated and thereafter compared with the outcome provided by the respondent. Comparing the estimated with the 'real' outcome resulted in the hit rates for both conjoint methods. Table 2 presents the hit rates for both methods, for all country clusters (hit rates over all diseases).

Table 2. Hit rates FP and ACA, per cluster

	Most likely situation		Least likely situation	
	FP	ACA	FP	ACA
Cluster 1	67.5	58.2	65.1	79.1
Cluster 2	74.5	74.4	81.4	69.8
Cluster 3	73.8	64.3	85.7	76.2
Cluster 4	70.7	75.6	80.5	73.2
Cluster 5	76.0	76.0	72.0	84.0

Hit rates for full profile were somewhat higher than those for ACA. For most clusters, the hit rate for the least risky situation was higher than the one for the most risky situation.

Table 3 illustrates the 'share of first preference' with the presentation of the results for Classical Swine Fever (with 19 respondents the most 'popular' disease among the total group of respondents), for cluster 1 (countries surrounding the Netherlands) and cluster 4 (Eastern Europe). These clusters are generally thought to be the most important concerning virus introduction.

Table 3. Share of first choice (%), CSF, clusters 1 and 4

	Cluster 1			Cluster 4		
	FP	ACA	Choice	FP	ACA	Choice
Situation 1	26.3	28.9	15.8	0.0	10.5	0.0
Situation 2	7.9	5.3	0.0	76.3	84.2	89.5
Situation 3	65.8	65.8	84.2	23.7	5.3	10.5
Total	100.0	100.0	100.0	100.0	100.0	100.0

According to this table, considering cluster 1, situation 3 was evaluated as the most risky, chosen by 84.2% of the participants. Both conjoint approaches estimate a lower percentage for this situation. In cluster 4, situation 2 was thought to be the most risky one (89.5% of the respondents chose this situation).

Table 3 shows that both conjoint methods estimate the same trend, which is also similar to the trend of the choice task. To obtain better insight into how closely both methods estimate respondents' choices, the 'mean absolute error' was calculated (based on Huber *et al.*, 1993). This measure indicates the absolute difference between the estimated and real share of each situation, for the choice task as a whole. The mean absolute error of the full profile method, for cluster 1, was calculated as follows (see also Table 3):

$$(|15.8 - 26.3| + |0.0 - 7.9| + |84.2 - 65.8|)/3 = 12.3 \qquad (2)$$

A total presentation of the values concerning CSF is given in Table 4.

Table 4. Mean absolute error, CSF, clusters 1 and 4

	Full Profile	ACA
Cluster 1	12.3	12.3
Cluster 4	8.8	7.0

5 Discussion and conclusion

So far results have provided interesting information about the possible applications of conjoint analysis in the field of animal health control. For a good comparison between the full profile and the ACA approaches, more information is needed. However, the preliminary results concerning the hit rates seem to favour the full profile method. In this experiment a maximum of seven attributes was used, which is about the maximum number suggested that can possibly be evaluated using the full profile approach (Green and Srinivasan, 1990). The small difference between full profile and ACA is therefore not surprising. A larger number of attributes will possibly favour the ACA approach.

Further research is under way and is aimed at obtaining more information on the predictive performance of both methods and possible influence of task order (first full profile or first ACA). Also the consistency of participants' answers will be evaluated further.

The 'golden standard', *i.e.*, the true value of the risk factors is difficult to obtain, if at all possible. It can be concluded, however, that methods such as the conjoint analysis technique are very useful in quantifying the subjective probabilities of experts about aspects concerning the introduction of virus. Not until historical data are available or experimental research is able to provide better data, do methods such as conjoint analysis provide a useful tool to obtain valuable information to be used in modelling risks and economic consequences of outbreaks of contagious animal diseases.

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