An Application of Conjoint Analysis in Agricultural Sustainability Assessment

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Abstract - **Increasing public interest in the concept of sustainable agriculture has resulted in the development of a number of methods that could be used for the assessment of sustainability of various agricultural production systems. Because of its complex, multi-dimensional nature, sustainability is most often assessed using numerous indicators, which make aggregate comparisons among systems difficult. In this paper we propose a methodology that could be beneficial in aggregate sustainability assessment. We apply conjoint analysis to identify economic, social, and ecological attributes that are perceived as important for agricultural sustainability by different stakeholders and to assess their relative impact on the overall sustainability measure.**

Keywords - **Conjoint analysis, choice experiments, sustainability assessment.**

I. INTRODUCTION

Increasing public interest in the concept of sustainable agriculture has resulted in a considerable resonance in scientific literature driven by the need to operationalise this concept [1, 2, and 3]. The common theme in the literature on agricultural sustainability assessment is that it embodies ecological, economic, and social dimensions [3]. Within each dimension of sustainability, one or more attributes are identified and then measured by the means of indicators. Indicators are used individually, as part of a set, or in the form of an aggregate index simultaneously considering all three dimensions for a holistic sustainability assessment. In the case of the aggregate sustainability measure, there is always a question of how the individual indicators or attributes should be combined into aggregated indices in a theoretically rigorous way. The choice of relative weights used previously for such aggregation was often arbitrary and controversial [4].

In this paper, we propose a theoretically-founded framework used to elicit people's perceptions of agricultural sustainability and to assess the relative impact/weights of its different attributes in the process of creating the aggregate sustainability measure. First, we identify an extensive list of potential attributes that could be used to define economic, social, and ecological sustainability in agriculture. We rely on the perceptions of a heterogeneous group of experts in different areas of sustainability. Next, we employ conjoint analysis (CA), a stated preference survey technique, to identify attributes that are the most important for agricultural sustainability based on the perceptions of stakeholders and to estimate their relative weights in the overall sustainability measure. In our application of the proposed method, we investigate the differences in the perceptions of sustainability between farmers and scientists.

II. THEORETICAL FRAMEWORK

A. Aggregate sustainability measures

A great number of studies have attempted to develop the methodological base for the assessment of sustainability of agricultural production systems. Many studies propose to assess sustainability by means of a set of indicators, each concentrating on a specific aspect of sustainability [e.g., 1, 5]. Such indicators are informative, but a large number of indicators make it difficult to compare/rank different production systems with respect to their overall performance. Thus, a more pragmatic approach towards quantifying sustainability would be to start from the three dimensions of sustainability (economic, social, and ecological) and work towards an integrated measure [2]. The assessment of sustainability of agricultural production systems then involves identifying meaningful sustainability attributes and finding a single metric of welfare that would allow combining them into an aggregate sustainability measure. The multi-attribute utility (MAU) approach is often used for this purpose [6]. The additive aggregate utility function is commonly assumed because of its simplicity. In the MAU approach, the utility function associated with production system *j* (*j*=1,…*J*) is represented as:

$$U_j = \sum_{k=1}^{K} w_k \, u_k(x_{kj}), \qquad (1)$$

where, w_k is relative impact/weight of the sustainability attribute *k* (*k*=1,…*K*), and u_k is the utility associated with attribute *k*, which is a function of x_{kj}, the level attribute *k* takes in the production system *j*. The functions u_k transform individual attribute measures into commensurable utility units. The methodology developed in this paper primarily concerns the elicitation of relative weights of individual attributes (w_k).

B. Weight elicitation methods

The weights indicating relative impact of individual components of the integrated sustainability measure should be developed based on solid theoretical foundation and input from major stakeholders [4]. Various methods have been proposed in the literature to generate such weights, each associated with certain disadvantages. For example, one method is to look at specific farm practices, and have a scientific team assignment a certain score to each practice based on how it contributes to sustainability [7]. However, it might not always be possible to reach a consensus among various stakeholders representing distinct interests. Another method involves surveying a sample of various stakeholders [3, 8]. Relative weights are estimated using attribute ordinal ranking and scale rating. In the case of attribute ordinal ranking cardinal information is not obtained, while in the case of scale rating respondents are not rating individual attributes relative to each other. More recent studies, e.g. [9], apply analytical hierarchy process, which uses pair-wise comparisons of the attributes, but this becomes difficult to apply in the settings where the number of sustainability attributes is large.

C. Use of conjoint analysis to estimate weights

Conjoint analysis has a long history in marketing research and is extensively used in environmental economics. Its critical assumption is that preferences for a good are a function of the specific attributes of this good rather than the good per se, which implies that the overall utility of a good can be decomposed into separate utilities of its attributes. In our application of this method, agricultural sustainability is presented as a bundle of various attributes. CA is used to assess stakeholders' preferences over various attributes and to estimate their relative impact on the aggregate sustainability measure.

The stakeholders are presented with two hypothetical sustainability profiles A and B. The utility of stakeholder *i* associated with a profile *j* (*j*=A or B) is represented as:

$$U_{ij} = \beta' x_{ij} + \varepsilon_{ij} \qquad (2)$$

where β is a vector of parameters to be estimated, x_{ij} is a vector of attributes of profile *j* presented to stakeholder *i*, and ε_{ij} is the stochastic portion of the utility function. Stakeholder *i* would choose profile A over profile B if $U_{iA} > U_{iB}$, and the probability of such choice is $P_i(\text{A}) = \text{Prob}\,\{\beta' x_{iA} + \varepsilon_{iA} \geq \beta' x_{iB} + \varepsilon_{iB}\}$. If we assume that the relationship between utility and the attributes of the profiles is linear in the parameters, and the error disturbances ε_{ij} are identically and independently distributed with a Weibull distribution, the probability of choosing profile *j* can be expressed in terms of a logistic distribution, $P(j) = \dfrac{exp\,(\beta' x_{ij})}{\sum_j exp\,(\beta' x_{ij})}$, which leads to the conditional logit model for the estimation of equation (2). The parameter estimates ($\hat{\beta}$) are then used to calculate relative weights of the individual sustainability attributes (w_k) in model 1.

III. DESIGN OF CHOICE EXPERIMENTS

A. Identification of sustainability attributes

A series of individual and group discussions were organized with experts in a variety of sustainability areas representing research institutions, governmental agencies, non-governmental environmental and farmer organizations. The experts were asked to identify attributes of four general sustainability components: economic, internal social, external social, and ecological. The resulting list of attributes is presented in Figure 1. The economic sustainability component includes attributes relevant to a farmer's ability to continue his farming business (i.e. economic viability of production). Internal social sustainability relates to farm safety and work conditions. External social component relates to the societal concerns about the impact of agricultural production on human and animal welfare. Finally, the ecological component includes attributes relevant to the impacts of production on ecosystem health. Variations in the qualitative attribute levels were used to present different versions of the good, "sustainable agriculture", to participating stakeholders, where each attribute can take two possible values representing undesirable and desirable attribute levels.

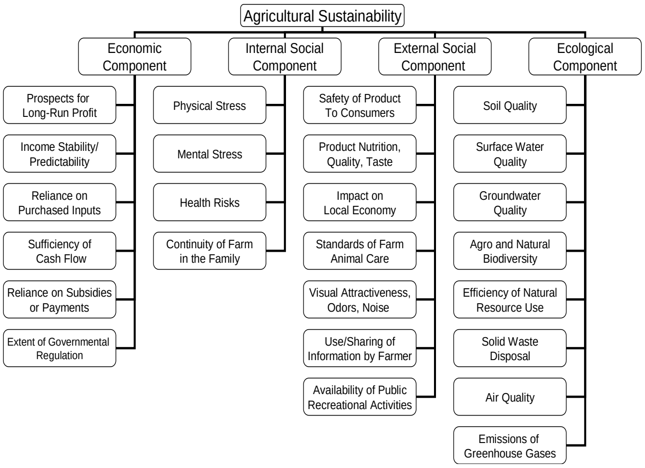

Fig. 1 Attributes of Agricultural Sustainability

B. Questionnaire design and survey administration

Our questionnaire is comprised of three sections. First, the purpose and details of the survey procedure are explained and general sustainability components are introduced. The second section is designed to extract the relative impact of various sustainability attributes. The questionnaire is concluded by a section where some demographic information is collected. The section with the attributes' relative impact questions directs respondents to one of the general sustainability components at a time and contains the conjoint choice experiments. Respondents were asked to examine two sustainability profiles that differ in the level of two or more attributes, and to indicate the profile which they believe is more sustainable. Survey administration began in November of 2006 and continued through January of 2007. The survey was self-administered in the "paper-and-pencil" format.

For each of the general components, a fractional factorial design, a subset of full factorial design, consisting of 48 profiles was created. Next, the fractional factorial design profiles were paired to allow each attribute level to appear with equal frequency in each choice experiment for balanced design. As a result, 24 choice experiments were generated for each general sustainability component. Twelve different versions of the survey were created, each containing two randomly selected choice experiments for each general component. The twelve survey versions were randomly administered to the respondents.

IV. RESULTS

A total of 480 surveys were distributed resulting in 120 completed surveys with a response rate of 25%. The analysis of the sample of survey respondents identified distinct stakeholder groups by the primary link to agriculture. The first group consists of 46 individuals (38% of responses) who stated that they work for a university, or non-governmental organization in the area of agricultural sustainability. The second group consists of 52 farmers (43%). In addition, 6 respondents identified themselves as agricultural suppliers and 16 respondents indicated that they have no specific link to agriculture other then consuming agricultural products. Both suppliers and consumers did not collect sufficient number of responses to be considered as separate stakeholder groups. The average survey respondent is 45 years old, has completed 16 years of formal education, and is a member of a household consisting, on average, of 2.6 persons with 0.7 persons being under 18, and with a yearly household income of $74,346.

The data were analyzed using the conditional logit procedure available in the SAS statistical software package. Estimation results for the relative impact of different economic, internal social, external social, and ecological sustainability attributes were obtained for three samples: sample containing all collected responses (N=120), sample containing responses from farmers only (N=52), and sample containing responses from individuals who work for a university or non-governmental organization in the area of sustainability (hereafter, scientists) (N=46).

In the estimation process, all sustainability attributes were coded as 1, if a certain attribute reaches the desirable value, or 0, if an attribute reaches the undesirable value. Since all attributes are presented on a uniform scale, estimated coefficients directly indicate relative impact of corresponding attributes on sustainability. For example, relative weight of long-run profit prospects on economic sustainability is calculated as the coefficient on this attribute divided by the sum of all statistically significant coefficients on economic sustainability attributes: $w_k = \frac{\hat{\beta}_k}{\sum_{k=1}^{K} \hat{\beta}_k}$. Relative weights calculated this way have the following properties: $0 \leq w_k \leq 1$, where k=1,…K, and $\sum_{k=1}^{K} w_k = 1$.

The standard errors of the relative impact estimates were generated with the help of the bootstrapping technique, where the estimated parameter vector, $\hat{\beta}$, and the variance-covariance matrix, $\hat{\Sigma}$, are used to generate 1,000 random draws from a multivariate normal distribution with mean $\hat{\beta}$ and variance-covariance matrix $\hat{\Sigma}$.

Economic sustainability results indicate that the respondents identified long-run profit prospects as the most important economic attribute. Its relative impact was estimated as 0.63. The choice experiment data for the sample containing all responses also indicate that the extent of governmental regulations (0.21) and reliance on purchased inputs (0.16) are also important. The same attributes and the degree of reliance on governmental subsidies are identified as important by scientists. The farmers concentrated on long-run profit prospects (0.69) and extent of regulation (0.31) as the only important attributes of economic sustainability.

Respondents identified mental stress level as the most important internal social attribute (0.35 based on the sample containing all responses). Continuity of farm within family was ranked second (0.28), health risks was ranked third (0.22), and physical stress level was ranked fourth (0.15). Farmers placed zero weight on physical stress and weighted mental stress and continuity of farm within family higher compared to scientists.

All respondents identified product safety to the final user as the most important external social attribute (0.53). Product nutritional value, quality, and taste were identified as the second most important attribute with relative weight of around 0.22. Scientists also identified production impact on local economy, while farmers identified visual attractiveness of production, standards of animal care, and the use of information as important for external social sustainability.

Respondents identified surface and groundwater quality as the most important attributes for ecological sustainability. In addition to these attributes, scientists emphasized the role of biodiversity (0.17) and solid waste management (0.16). On the other hand, farmers concentrated on efficiency of natural resource use (0.11), solid waste management (0.16), and emissions of greenhouse gasses (0.20).

V. DISCUSSION AND CONCLUSSIONS

Both scientific quality of information and stakeholder acceptance are important for the development of an effective sustainability assessment tool. This paper demonstrates how conjoint analysis could be used as a standardized tool for sustainability assessment and comparison of stakeholder perceptions of what is important for sustainability. The analytical framework proposed here reduces the complex sustainability issue to a simpler format where respondents are encouraged to concentrate on few attributes which are the most important to them, and their decision is based on relatively realistic trade-off situations. The proposed method avoids some of the problems that are associated with the alternative methods and relies on the solid theoretical foundations of utility maximization in the multi-attribute setting. The results of such analysis could be linked to the specific indicators in order to derive aggregated indices of social, economic, and ecological sustainability.

Our survey results indicate that the choice tasks are easy to carry out. In the majority of cases the respondents were able to make their choices and did not utilize the “Don’t know” option. The results also indicate that, when facing a choice situation, respondents are willing to make trade-offs among attributes; they accept an undesirable value of attribute less important to them for a desirable value of an attribute that is very important.

The assessment of agricultural sustainability is a complex process involving several stages, such as identification of involved stakeholder groups and attributes that could be used to define sustainability, selection of weights that reflect relative impact of individual attributes on the overall sustainability, etc. In this study, we concentrated our effort on development of a better way to extract relative weights and not on the identification of the stakeholders. But as in other multi-criteria decision methods that are based on stakeholder participation, the results are of a subjective nature reflecting the preferences of involved stakeholders. Therefore, appropriate representation of stakeholder interests and all relevant opinions are required in further applications.

In fact, our applications of the method revealed some significant differences in the perceptions of sustainability by farmers and scientists. Conjoint analysis enables the issue at stake to be assessed at the level of small stakeholder groups or individual respondents. If socio-economic, geographical, or demographic information is available, respondents can be (re-)grouped in various meaningful ways, and contrasts in opinion can be drawn. Thus the statistical results of the analysis help make the differences in stakeholder perceptions of sustainability transparent. Finally, following stakeholders over several years and repeating the survey could yield interesting information on changing perceptions and preferences over time providing insights into the progress of the debate on agricultural sustainability.

Part of the problem with linking scientific input and participation research is the natural scientists’ and other stakeholders’ unfamiliarity with the elicitation methods. This study is an illustration of how behavioral economics methods can be used to support sustainability research. The proposed approach allows engaging stakeholders at all analysis stages, which enhances understanding of the procedure and acceptance of the outcomes.

REFERENCES

1. Rasul, G. and Thapa, G., 2004. Sustainability of ecological and conventional agricultural systems in Bangladesh: an assessment based on environmental, economic and social perspectives. Agricultural Systems, 79:327-351.
2. Sands, Gary and Podmore, T., 2000. A generalized environmental sustainability index for agricultural systems. Agriculture, Ecosystems and Environment, 79:29-41.
3. Van Calker, K., Berentsen, P., Giesen, G., and Huirne, R., 2005. Identifying and ranking attributes that determine sustainability in Dutch dairy farming. Agriculture and Human Values, 22:53-63.
4. Stoorvogel, J.J., Antle, J.M., Crissman, C.C., and Bowen, W., 2004. The tradeoff analysis model: integrated bio-physical and economic modeling of agricultural production systems. Agricultural Systems, 80:43-66.
5. Reganold, J., Glover, J., Andrews, P., and Hinman, H., 2001. Sustainability of three apple production systems. Nature, 410(19 April):926-930.
6. Hajkowicz, S. 2006. Multi-attributed environmental index construction. Ecological Economics, 57:122-139.
7. Taylor, D., Mohamad, Z., Shamsudin, M., and Chiew, E., 1993. Creating a farmer sustainability index: A Malaysian case study. American Journal of Alternative Agriculture, 8(4):175-184.
8. Chandre Gowda, M. and Jayaramaiah, K., 1998. Comparative evaluation of rice production systems for their sustainability. Agriculture, Ecosystems and Environment, 69:1-9.
9. Krajnc, D. and Glavic, P., 2005. How to compare companies on relevant dimensions of sustainability. Ecological Economics, 55:551-56.