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A Comparison of the Methods Used to Elicit Producers' Goals

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Abstract: The methods used to elicit the goals of producers are discussed. After explaining the basic pair-wise comparison, magnitude estimation and analytic hierarchy processes, fuzzy pair-wise comparison method is explained in detail. The result shows that the fuzzy pair-wise comparison method can better asses the value of goals that producers have.
Key Words: Multidimensional goals, decision making, fuzzy pair-wise comparison

Üretici Amaçlarını Belirlemede Kullanılan Metotların Bir Karşılaştırması

Özet: Üreticilerin amaçlarını belirlemede kullanılan metodlar tartışılmaktadır. Basit Birebir Karşılaştırma, Önem Tahmini ve Çözümsel Hiyerarşi Yöntemleri kısaca anlatıldıktan sonra, Belirsiz Birebir Karşılaştırma Metodu detaylı bir şekilde açıklanmaktadır. Sonuç, Belirsiz Birebir Karşılaştırma Metod'unun üretici amaçlarının değerini daha iyi ölçebildiğini göstermektedir.
Anahtar Kelimeler: Çok yönlü amaçlar, karar verme, bulanık mantık birebir karşılaştırma

Introduction

The way of assessing the Producers' goals has long been of concern to the agricultural economics profession, beginning with the earliest agricultural economists in the early 1900s. Researchers such as Smith and Capstick, Patrick et al., Van Kooten et al., Fairweather, and others have suggested that producers' goals should be considered in multi-dimensional framework rather than uni-dimensional. Multiple goal approaches allow for a more accurate assessment of producers' preferences. Thus, better predictions can be made regarding producers' actions when multiple goals are considered (Barnett et al., 1982).

In production, the resources are allocated according to the producer's hierarchical weight of goals. Economists often assume that the limited resources are allocated in such a way that profit can be maximized. In a business, besides maximizing profit, some other goals may also be important and their weight in decision making process needs to be examined.

As discussed by Barnett et al., multiple goals of farmers need to be taken into consideration in research. While some of the goals may be complementary, others may be competitive. The satisfaction received from the attainment of goals is "utility." Howard defined utility as "... the satisfaction one receives from consuming a good or a service or engaging in some activity." Maximizing profit may have some weight in a farmer's utility, but some other goals such as having time for other activities, staying in business, being one's own boss and others may be important, as well. As discussed by Barnett et al, many different goals beside maximizing profit or minimizing the cost of production can add to the utility a farmer receives from Participating with an activity.

The researcher may not be able to obtain all necessary information regarding a respondent's goals, how they change over time, and how they are used in a particular decision making process. It is, however, useful to obtain the information regarding the hierarchical ranking of goals and how their structures change under different business planning conditions. By having multiple goals in a business, a producer is assumed to satisfy as many of the goals as possible. The producer will first try to satisfy the most important goal or goals, then less important goals will be pursued (Smith and Capstick, 1976).

Results of the assessment of the relative importance of multiple goals in a multidimensional framework allow one to better understand the decision-making processes of producers. Knowing the hierarchical ranking of goals helps a researcher to better understand the motivations of producers in an industry, lending insight as to why producers make the decisions they do and why the industry has evolved as it has. That is why the way of finding the hierarchy of goals (from the most important one to the least important one) needs to be searched

The main objective of this study is to determine and explain the pair-wise comparison techniques to evaluate the hierarchy of the goals that producers have in their decision making process. The techniques will be discussed in a multi-dimensional framework.

In this study the methods used in the literature to find the weight of goals will be explained, their advantages and disadvantages will be discussed and then the most useful one, Fuzzy pair-wise Comparison, will be given in detail.

Methods that Have Been Used by Previous Researchers to Elicit Goal Hierarchies

In this discussion, the methods for eliciting goal hierarchies will be narrowed to several well-known methods. These methods include the use of basic pair-wise comparisons, ratio scales (also known as the magnitude estimation), the analytic hierarchy process (AHP) and the fuzzy pair-wise comparison. The basic pair-wise comparison method was widely used by researchers prior to the 1970's. The other three are modified forms of pair-wise comparison methods. As Patrick and Blake, and Van Kooten et al., have discussed, each of these methods has been widely used by researchers for multiple goal studies. After reviewing the pair-wise comparison methods, the fuzzy pair-wise comparison procedure will be discussed in detail and proposed as the most useful one.

The Basic Pair-Wise Comparison

The basic pair-wise comparison method is based on the producer's comparative judgment between paired goals according to the importance of one goal over the other. The process begins with defining the goals of the decision maker. With n goals, there are $n(n-1)/2$ possible paired comparisons to be made. The subject is provided with the pairs and asked to define which goal in the pair is more important to him/her. Since the method does not allow equality judgment or indifference, the subject must claim one of the goals to be of greater importance. A goal is not allowed to be compared with itself (Torgerson, 1958).

The method of pair-wise comparison is discussed by well-known researchers such as Thurstone (1927), Bradley and Terry (1952), Stevens (1957), Torgerson (1958), Carriere and Finster (1992), Bryson et al. (1995), and others. Following Torgerson, the procedure can be explained as follows. From the comparison of $n(n-1)/2$ paired goals, the researcher will have as raw data the number of times each goal was judged by the population to be more important than each of the other goals. From these raw data, a n square F matrix is formed as

$$F = \begin{bmatrix} - & f_{12} & f_{13} & \cdot & \cdot & \cdot & f_{1k} \\ f_{21} & - & f_{23} & \cdot & \cdot & \cdot & f_{2k} \\ f_{31} & f_{32} & - & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & - & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & - & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & - & f_{j-1k} \\ f_{j1} & f_{j2} & \cdot & \cdot & \cdot & f_{jk-1} & - \end{bmatrix} \quad (1)$$

Where j, k = 1,2,....n, each element of the matrix and, f_{jk} denotes the observed number of times goal k was judged by the population to be more important than goal j. Since a goal cannot be compared with itself, the diagonal elements of the matrix are left vacant. The matrix has symmetric cells. The total number of cells located on one side of the diagonal in the matrix is equal to the total number of paired comparisons, $n(n-1)/2$.

A P matrix is constructed from the F matrix as shown in (2.2).

$$P = \begin{bmatrix} - & p_{12} & p_{13} & \cdot & \cdot & \cdot & p_{1k} \\ p_{21} & - & p_{23} & \cdot & \cdot & \cdot & p_{2k} \\ p_{31} & p_{32} & - & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & - & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & - & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & - & p_{j-1k} \\ pf_{j1} & f_{j2} & \cdot & \cdot & \cdot & p_{jk-1} & - \end{bmatrix} \quad (2)$$

The elements of the P matrix contain information on the observed proportion of times goal k was preferred to goal j. The cells of the matrix can be calculated as $p_{jk} = f_{jk}/m$, where m is the number of respondents. Like the F matrix, the diagonal cells of the P matrix are left vacant. The summation of the symmetric cells equals unity. For example, $p_{12} + p_{21} = 1$.

From matrix P, a basic normalized transformation matrix X is constructed.

$$X = \begin{bmatrix} - & x_{12} & x_{13} & . & . & . & x_{1k} \\ x_{21} & - & x_{23} & . & . & . & x_{2k} \\ x_{31} & x_{32} & - & . & . & . & . \\ . & . & . & - & . & . & . \\ . & . & . & . & - & . & . \\ . & . & . & . & . & - & x_{j-1k} \\ x_{j1} & x_{j2} & . & . & . & x_{jk-1} & - \end{bmatrix} \quad (3)$$

Each element of X is the unit normal deviate corresponding to the element p_{jk} and can be obtained by normalizing the P matrix. The elements of the X matrix will be positive for all values of $p_{jk} > 0.50$, and negative for all values of $p_{jk} < 0.50$. The X matrix is skew-symmetric: the summation of the symmetric elements is zero, or $x_{jk} = -x_{kj}$. The weight of each goal can be obtained by averaging the column of the matrix X.

A problem with this method is that it requires respondents to make an "all-or-nothing" choice for each paired comparison (Van Kooten et al., 1986). The respondents must designate one of the goals as more important. Thus, the method is inadequate in the case of pairs with equal weights. As a result of this weakness, the following simple pair-wise comparison based methods have been developed. By using the simple pair-wise method Smith and Capstick found that "Stay in business" and "increase farm size" as the most and least important of farmer goals, respectively.

Magnitude Estimation

Another method which has been used to assess farmers' goal structures is the magnitude estimation procedure. The method was developed by Stevens (1957). With this procedure, a standard goal is presented to the respondent. An arbitrary value is given to the goal to be considered as its magnitude. Then, the respondent is faced with a series of comparison goals. The respondent is expected to estimate the magnitude of each comparison goal with respect to the magnitude of the standard.

For example, suppose goal A is chosen as the standard goal and given a 100-point value. Then, respondents would be asked to evaluate all other goals relative to this standard goal. If the compared goal were valued as twice as important as the base goal, it would receive a value of 200. By changing the standard goal and reassessing, it would be possible for the researcher to test for consistency in a farmer's responses.

The major disadvantage of magnitude estimation is that the elicitation procedure is relatively time consuming. In order to conserve the respondent's time, pair-wise comparisons are not made among all combinations of goal pairs. With this elimination, the researcher assumes that transitivity among goals holds. Examples of studies that have used the magnitude estimation procedure are Patrick and Blake (1980), Patrick et al., (1981), and Patrick (1983).

Using magnitude estimation, Patrick et al. showed that avoiding being unable to meet loan payments and/or avoiding foreclosure and attaining a desirable level of family living were the top ranked goals among farmers.

Analytic Hierarchy Process

The analytic hierarchy process (AHP) model, developed by Saaty (1980), is used to obtain a ratio scale of importance for n goals. "The basic principle of the procedure involves setting up a matrix consisting of observations or judgments based on pair-wise comparisons of the relative importance between and among the elements" (Mendoza, 1989).

If we have n goals being considered by a group of farmers, the objective would be to provide a quantitative judgment on the relative importance of the goals. A pair of goals would be given to the producer as shown in Figure 1. The producer would be asked to place a mark or "×" in the brackets that best represents his/her preferences. The midpoint (equal) of the figure indicates indifference between the two goals. As Saaty indicated, the goals will receive the values between 1 (denoting equal importance) and 9 (denoting absolute importance) depending on the preferences of the producer. The values between 1 and 9 show different degrees of importance from weak to extreme.

Figure 1. Analytic Hierarchy Process for Making Comparison Between G_i and G_j.

Column I	*Abso- lute*	*Very Strong*	*Strong*	*Weak*	*Equal*	*Weak*	*Strong*	*Very Strong*	*Abso- lute*	*Column II*
G_i	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	G_j

The AHP has been used by researchers such as Saaty, Islam et al., Datta et al., Kim at al., Schniederjans et al., and Ball and Srinvasan.

Fuzzy Pair-Wise Comparison

Fuzzy set theory was developed by Zadeh. Partial membership is a central concept to the theory. In standard full membership theory, "a set is a well-defined collection in the sense that each element of the universal set is either a full member of it (gets a mark of 1) or not a member (gets 0)" (Basu, 1984). On the other hand, by having partial membership, the fuzzy set is mapped over a [0, 1] closed interval. Thus, an element is assigned a value between 0 and 1, representing the partial membership that the element has in the fuzzy set (Van Kooten et al., 2001).

Fuzzy set theory is based on vague preferences. "The concepts formed in human brains for perceiving, recognizing, and categorizing natural phenomena are often fuzzy concepts. Boundaries of these concepts are vague. The classifying (dividing), judging, and reasoning emerging from them also are fuzzy concepts" (Li and Yen, 1995). Fuzzy reasoning may be used to judge the preference between paired goals.

The method of fuzzy pair-wise comparison has been used by researchers such as Spriggs and Van Kooten, Ells et al., Krcmar-Nozic et al., Mendoza and Sprouse, and Boender et al. The methodology is similar to the previous pair-wise comparison procedures in that the respondent is asked to compare two goals. However, unlike some of the previous methods, the respondents are not forced to make a binary choice between two goals. The degree of preference of one goal over another is elicited. As such, the respondents are also allowed to be indifferent between two goals. Unlike magnitude estimation, with this methodology, the scale value of each goal is based on the entire set of compared pairs. With this method, the idea is relatively straightforward, but requires more comparisons of paired goals than the simple pair-wise procedure.

A unit line segment as illustrated in Figure 2 is used. Two goals, X and Y, are located at opposite ends of the unit line. Surveys are conducted such that the respondent is asked to mark an "×" on the line to indicate his/her preferences. In comparing the two goals, whichever has the shortest distance to the mark is preferred to the other. The degree of the preference of X over Y, R_{XY}, is measured from the mark to the X where the total distance from X to Y equals 1. If $R_{XY} < 0.5$, Y is preferred to X; if $R_{XY} = 0.5$, then X is indifferent to Y; likewise if $R_{XY} > 0.5$, then X is preferred to Y. In the case of absolute preference for one alternative, R_{XY} takes the value of 1 or 0.

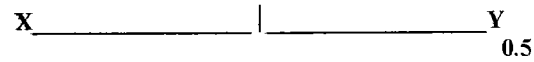

Figure 2. Fuzzy Pair-Wise Approach for Making Comparison Between X and Y.

The number of pair-wise comparisons of goals, K, can be determined by a simple equation;

$$K = n*(n-1)/2 \qquad (4)$$

where n = the number of goals.

For each paired comparison, R_{ij} $(i \neq j)$ is obtained. The measurement of the degree by which j is preferred to i can be obtained as $R_{ji} = 1 - R_{ij}$. After obtaining the measurements, the individual's fuzzy preference matrix R can be constructed using the following elements;

$$R_{ij} = \begin{cases} 0 \ \ if \ \ i = j \ \forall \ \ i, j = 1, \ldots, n \\ r_{ij} \ \ if \ \ i \neq j \ \forall \ \ i, j = 1, \ldots, n \end{cases}$$

Following Van Kooten at al., the method can be explained simply by the $i \times j$ fuzzy preference matrix (R) such that

$$R = \begin{bmatrix} 0 & r_{12} & r_{13} & \cdot & \cdot & \cdot & r_{1j} \\ r_{21} & 0 & r_{23} & \cdot & \cdot & \cdot & r_{2j} \\ r_{31} & r_{32} & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & 0 & r_{i-1j} \\ ri1 & r_{i2} & \cdot & \cdot & \cdot & r_{ij-1} & 0 \end{bmatrix} \quad (5)$$

where each element of the matrix is a measure of how much goal i is preferred to goal j and takes on values in the closed interval [0, 1].

Now, it is possible to calculate a measure of preference, i, for each goal from the individual's preference matrix. The formula (6) measures the intensity of each goal separately.

$$I_j = 1 - \left(\sum_{i=1}^{n} R_{ij}^2 / (n-1)\right)^{1/2} \quad (6)$$

The value of I_j ranges between 0 and 1. As the value gets closer to 1, a greater intensity of preference (greater utility) for the particular goal is achieved. In this situation, by examining the values of I_j, the n goals can be ranked from most to least important.

Van Kooten et al. (1986) evaluated the goal ordering of Saskatchewan farmers. By using the fuzzy pair-wise comparison method, they determined that avoiding low profits/losses, reducing farm debt, and making more profit were the most important three goals.

Conclusion

The four methods eliciting the goals of producers, have been discussed. There are some disadvantages with the first three methods. For example, the simple pair-wise method does not allow equality judgment or indifference; the subject must claim one of the goals to be of greater importance. A goal is not allowed to be compared with itself (Torgerson, 1958). On the other hand, the major disadvantage of magnitude estimation is that the elicitation procedure is complicated and time consuming. It does not give an idea over the entire comparison. This problem can give such results which might be against to the transitivity property of utility function. In analytic hierarchy process the distance between the choices, for example weak and equal, is not clear when comparing with the other degree levels.

The methodology of fuzzy pair-wise method is similar to the other pair-wise comparison procedures. However, unlike them, the respondents are not forced to make a binary choice between two goals. The degree of preference of one goal over another is elicited. As such, the respondents are also allowed to be indifferent between two goals. The scale value of each goal is based on the entire set of compared pairs. With this method, the idea is relatively straightforward. Since the method does not have the weakness of all other three, it can be proposed as the most applicable technique among the others in comparing goals.

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