Analysis of Farmer´s Information – Decision System with Stochastic Linear Programming

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Abstract

Information is like any other production factor, its acquisition and integration in the production process involves costs and generates benefits. Therefore the quality and quantity of information must be optimized and not maximized. This paper formulates a Stochastic Linear Programming model for the Azores dairy farms which explicitates the information on prices, subsidies, and soil analysis and milk quality. Finally, the model is simuleted for different scenarios of farmer´s decision making process.

Key words: decision models, stochastic linear programming, information, Azores, dairy farm.

1-Introduction

This paper contains a formulation of stochastic linear programming model that is able to capture the information decision system of the Azorean dairy farmers. First a conceptual information decision system is presented (2) and then a conceptual stochastic linear programming model is designed to integrate the information and decision process within the optimization procedures (3). The next part contains the application of this model to the Seven Cities dairy farms (4) which is followed by the discussion of the results (5).

2 – Conceptual information-decision system

Figure 1 presents a conceptual information-decision system used by many information theorists (Demski, 1980; Strong&Walker, 1988; Phlips, 1989; and others. This operational tool divides itself into three subsystems. The first is the information structure that transforms data about states of the world into signals (Nermuth, 1981), which then have meaning for the receiver (Shannon, 1987). This structure symbolises the process "information that" and I will call it the Information Structure (x) of entity (k), represented by [$^{k}I_{x}$] which components can be seen as conditional probabilities [$^{k}\theta(s|f)_{x}$] of a signal [s] given a revealed fact (or data) [f].

The second subsystem is a decision rule that relates signals with acts and is a representation of the process "information how". This subsystem is designated as the decision structure (y) of entity (k), represented by [$^{k}D_{y}$], which components can also be seen as conditional probabilities [$^{k}\theta(a|s)_{y}$] of acts [a] given signals [s].

Combining the information structure [$^{k}I_{x}$] with the decision structure [$^{k}D_{y}$] we get a particular (xy) information-decision structure [$^{k}ID_{xy}$] of entity k, which components are the conditional probabilities of acts given facts [$^{k}\theta(a|f)_{xy}$].

(1) $$^{k}\theta(a|f)_{xy} = \int_{a}\int_{s} [^{k}\theta(s|f)_{x}.^{k}\theta(a|s)_{y}]\delta s\delta a$$

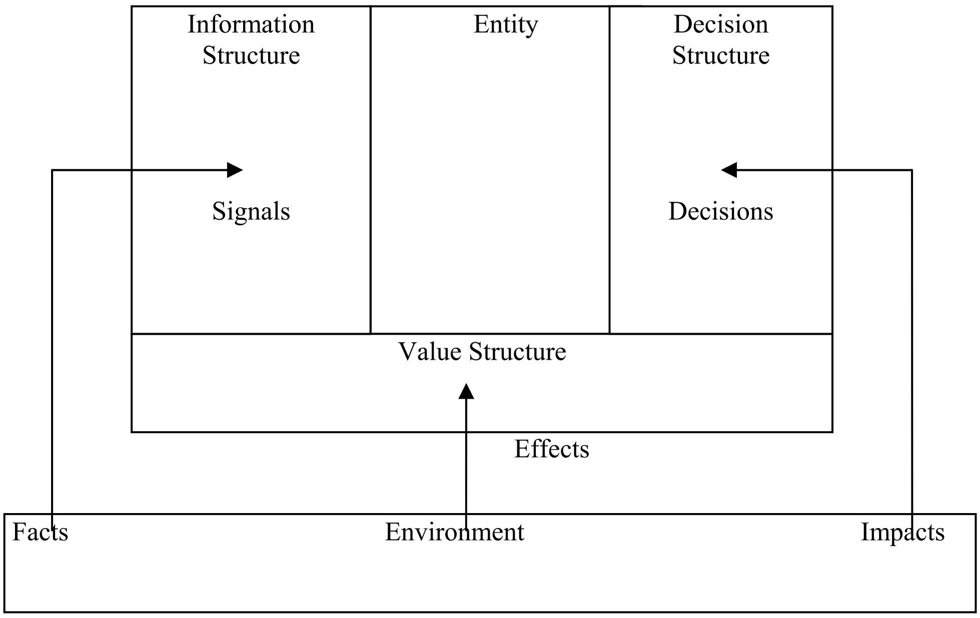

Figure 1: Information-Decision Module

Moreover - and here comes the third subsystem - if for each entity (k) it is possible to relate each pair (fact, act) with a certain result [${}^kR(a,f)$], then it is also possible to estimate, for each scenario [f], the expected effects of each information-decision structure [${}^kR_{xy}(f)$], given a certain fact [f]:

(2) $${}^kR_{xy}(f) = \int_a [{}^kR(a,f).{}^k\theta(a|f)_{xy}]\delta a$$

Additionally, if we know the probability of each scenario [P(f)], then each information-decision structure (xy) can be related with a certain expected result [${}^kR_{xy}$]

(3) $${}^kR_{xy} = \int_f [{}^kR_{xy}(f).\theta(f)]\delta f$$

The different structures of this information-decision module - shown in formulas 1 to 3 - can be represented by matrices (Dentinho, 1991), or simulation models (Dentinho, 1996) or by probabilistic functions as was also done in the work by Marschak and Radner (1972). Yet, the intention in the present paper is to obtain a more operational model and for that a conceptual stochastic linear programming model is designed to integrate the information and decision process within existing optimization procedures (Silva, 2001; Calado and Dentinho, 2004).

3 – Stochastic linear programming for farmers' information-decision systems

A linear programming model aims to select from a set of possible acts (x_i) of a decision maker those which better accomplish his objectives ($Z= \Sigma_i d_i x_i$), subject to the restrictions of his capacities (b_j) and the constraints of the available technology (a_{ij}).

This is done with a well known mathematical format and quite diffused algorithms (see for instance Hillier and Lieberman, 2001).

Stochastic linear programming can be applied when some or all the coefficients (d_i; b_j; or a_{ij}) are replaced by stochastic variables. This can be done by introducing into the models either the probability distributions, or the correlations between stochastic variables, or even the decision maker's attitude towards uncertainty. Concerning linear programming models one of the more diffused ways to face the issue is to include stochastic variables in the objective function or in the constraints (Hanf and Schiffer, 1983). In the present paper the consideration of stochastic variables in the objective function is used to represent the information structure of expression (1), whereas the inclusion of stochastic variables in the constraints is due to attend the decision structure of expression (2). It is assumed that the farmer has some uncertainties concerning the coefficients of the objective function, where prices and subsidies play a crucial role, and also has some lack of information how expressed by and uncertainty related to the constraints.

The linear programming model without stochastic variables is the following one:

Variables:

The model is formed by 102 decision variables (x_i) including forage production; meat and milk production; forest production; and man power;

Objective Function

$$MAX\ MB = \Sigma_i d_i x_i$$

Where d_i = gross margin for the activity (x_i).

Constraints:

- Area

$$\Sigma_i x_i \leq a \qquad \text{for all types of area (a)}$$

- Man power;

$$\Sigma_i a_{ij} x_i - xl_j \leq 0 \qquad \text{for all bimestres (j)}$$

Where xl_j = hours of labour generated in bimestre (j).

- Animal nutrition requirements:

$$\Sigma_i a_{ij} x_i \geq f_j \qquad \text{for all (j) and all type of nutrients (f)}$$

Where f_j = amount of feed (f) needed per animal in bimestre (j).

The inclusion of stochastic variables in the objective function is done only for the gross margin of the produced. This represents the farmer's uncertainty about the quality of milk produced and also about the amount of money that must be paid by the farmer if the milk quota is overcome cumulatively at the national, regional, industry and farm level. To implement this, the former objective function is transformed into five constraints (I, II, and III) where the only difference is in the coefficient for the margin of milk (d_{mI}, d_{mII}, d_{mIII})

(4) $d_1x_1+ d_2x_2+ \ldots+ \mathbf{d_{mI}x_m}+ d_ix_i+ d_ix_i - z_I = 0$ for I = I to III

And the new objective function is:

(5) $\text{Max } U= \Sigma_I q_I z_I$

where q_I are the probabilities associated with d_{mI}. Therefore if there is no uncertainty q_{III} = 1 and all the other values q are zero, and d_{mIII} is the true value for the margin. On the other hand if there is any uncertainty concerning the margins that can be represented by different distributions of q_I.

The consideration of stochastic variables in the constraints is implemented for the amount of forage (UF) that exists in the farm for each bimestre. This represents the farmer's uncertainty about the quantity of food available in the farm. To do this, the each constraint related to forage is transformed into two constraints (v,w), and each one of them gets one more variable y_{jv} , y_{jw}.

(6) $a_{11}x_1+ \ldots+ a_{ij}x_j+ \ldots- \mathbf{y_{jn}} = b_{jn}$ for n = v and w.

And the new objective function must include some new elements:

(5) $\text{Max } U= \Sigma_I q_I z_I \mathbf{- \Sigma_{jn}(p_{jn}d_n)y_{jn}}$

where p_{jn} are the probabilities associated with the realization of the constraint (jn) and d_n is cost associated with the violation of constraint (jn) for one unit of y_{jn}.

4 – Application of the model to the farmers of the Seven Cities basin.

The Seven Cities basin is located in the volcanic crater. The basin has 1923 hectares, 25% of which is covered with water. The remaining areas are pastures (450 hectares) production forest (380 hectares) wild forest (450 hectares and other areas including social areas (160 hectares). Precipitation is 1600 mm.

For the model the basin is divided into 10 different zones, organised into two sub-basins: cemetery basin and other basins. Each zone can be occupied by alternative uses: pasture, extensive pasture (50% of fertiliser), wheat-autumn, extensive wheat-autumn, pasture with silage, production forest, wild forest. Forages and feed are able to support dairy cattle that produce milk and beef. Different land uses generate different amounts of phosphorus that goes into the lagoon through one of the two sub-basins.

Figures 1 and 2 show some results of the model simulation. On the one hand the perception of milk prices seems to have a string effect in the production of milk. On the other hand information concerning the amount of feed available in the farm seems to have not only a much reduced influence on the decision about milk production but that decision is not always taken in the same direction. For instance a perception of a low price and a good knowledge of the limited feed of the farm leads to a reduction in the level of production, whereas a higher perception of the price of milk some misunderstanding about the amount of feed can lead to higher or lower levels of milk production.

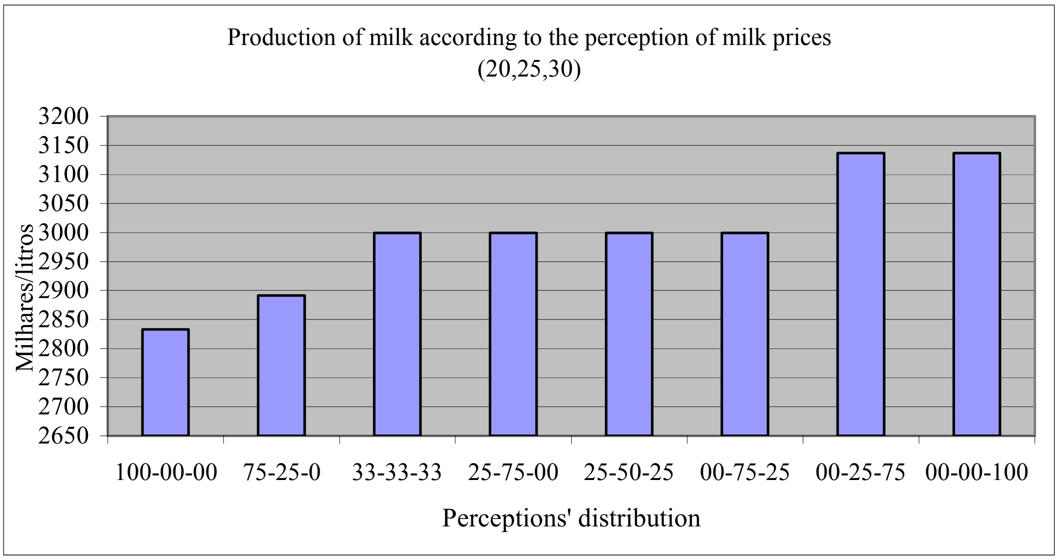

Figure 2: Production of milk according to the perception of milk prices

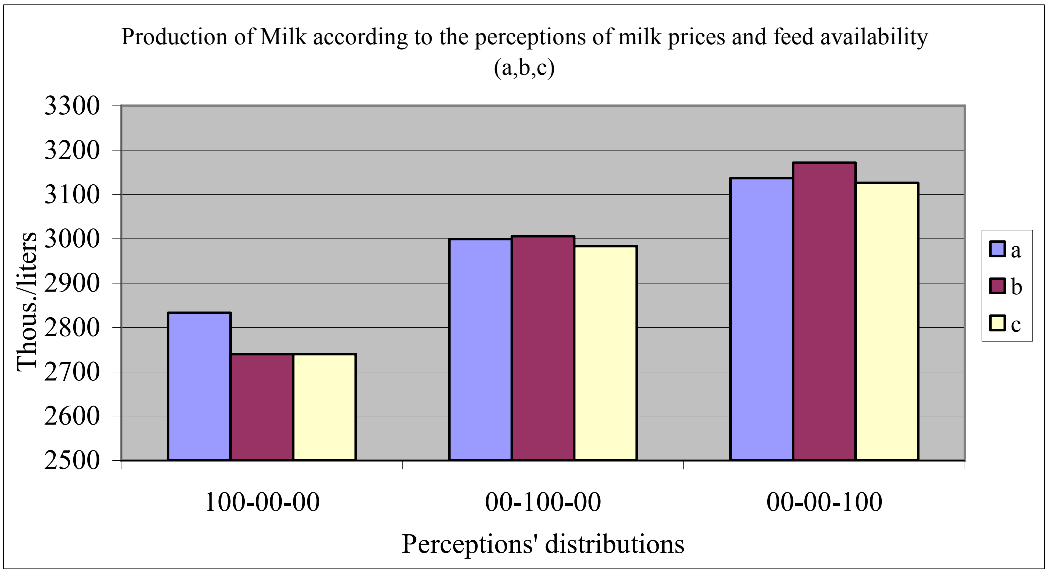

Figure 3: Production of milk according to the perception of milk prices and feed availability

5-Conclusion

A stochastic linear programming model can include the information decision system of farmers. This method could be used to assess the information system of farmers and also to understand the relative importance of various types of information for the farmer gross margins.

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