International Journal of Strategic Property Management (2004) 8, 1–9

A MULTICRITERIA MODEL FOR SELECTING ELIGIBLE BUYERS FOR LAND CONSOLIDATION

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Received 10 November 2003; accepted 19 March 2004

ABSTRACT. The problem of land consolidation is very relevant and Agricultural Policy has ruled particular conditions in the sales of farms. The adjacent neighbours must be involved (pre-emption right) and in the case of more than one available for the stated price, the choice of the candidate having priority is not an easy task. It has, then, to be considered not only the subjective ability of the farmer, but also the nature, productivity, endowments of his farm with respect to the adjacent one in sale. The adopted procedure takes into account all the attributes related to the farm on sale, to the prospective buyers and their farms. The acquired information are evaluated by an entropy decisional process. The best solution is gained with respect to an ideal point, representing the perfect decision and having minimum entropy.

KEYWORDS: Land consolidation; Farm; Preference; Attractiveness; Ideal point; Ranking

1. INTRODUCTION

The Italian Civil Law favours land consolidation, amongst other policy instruments, by enforcing the obligation on the part of the seller of a farm, or a plot of land, to notify to all adjacent neighbours the price and conditions for sale, agreed with a prospective buyer. If a neighbour agrees to the same conditions, he will have by law preference in the transaction (pre-emption right).

So far Law Courts have ruled that, when more than one adjacent neighbour accepts the stated price, the land should be split amongst them, or otherwise be given to only one farmer, the one who could gain most out of the deal. The choice of this candidate is not an easy task when eligible farmers are fairly much the same; in addition the concept of gain does'nt rest only on the subjective ability of the farmer, but also on the nature, productivity and endowments of his farm with respect to the adjacent one on sale.

The items, therefore, to be considered are manifolds and the eventual decision will rely on many attributes. The decisional process would point out an absolute index able to reassume all the acquired information about the farm or farmer, to collect the preferences assigned to the attributes and to caracterize the suitable pre-emption right. Such an index, varing according to different features of the farms, should take into account also the differentiation [1, 2] made inside the expressed preferences.

An application of the model will make its use, we hope, quite clear and will allow for fruitful discussion.

2. THE ALLOCATION PROCESS OF COMPETED LAND

The sale-purchase transaction of rural land, be it a big estate, or a small allottment, or more frequently a farm as a productive unit, has always been a rather complex venture. Many aspects restrict a smooth negotiation, from the legal, to the agro-technical, administrative, fiscal, socio-antropological points of view.

In the past centuries, and to some extent also nowadays, the acquisition of land meant a rise in social status by farmers, becoming landlords from labourers', or paesants', or sharecroppers' condition. On the other hand, the sale of land meant a demotion of status for the landed gentry, both from aristocratic or burgeois origin.

This is why the value of land included a peculiar feature, called rent, which usually determined an increase above the determinants of its sheer productivity. Of course, land is not only a production input, but to the farmer it means a way of life, the dwelling, the security of a job, also for his family, and a capital assett.

All this explains the great interest that in all legislations is devoted to land transactions, in terms usually to protect farmers from outsiders as buyers (quite often more affluent than the former) both national and foreigners.

In most of the cases this protection leads to an increase of transparency in the land transactions and this is acquired by notifying to all adjacent neighbours the terms of the sale. As we shall see in the following paragraphs, a sort of strategic game arises in this context between the seller, the prospective buyer and the neighbours, who are by law allowed to take the place of the buyer at the stated price, if they are interested in the transaction. When more than one buyer as neighbour competes for the same land than we have the problem of choosing one out of two or more.

The aim of improving transaction conditions of land amongst farmers (i.e.) giving them preferential terms with respect to buyers, other than farmers, is a widely recognized goal in many Agricultural Policy statements.

As already mentioned before, socio-institutional considerations appeal to rural population, which in the past has been a strong electoral body, in preserving the "national rural estate" in the hands of paesantry. Also techno-economic reasons, however, suggest that a process of consolidation, i.e adding one field to the adjacent, leads to more viable farms, to higher productivity in farming operations, to higher incomes because of cost reductions due to economies of scale (size).

All these features justify in political terms to issue the right of pre-emption, but, in the case that more than one neighhour sets to challenge the stated price, the problem of choosing the "right" farmer to whom to grant the deal rises. Of course the possibility that the land in question be split between the challangers is ruled out because by subdiving a farm, or a plot, the consolidation effort is minimized.

The selection of the "most suitable" candidate is a typical decision making process that can not be solved according to a single criterion of choice i.e. the age of the farmer, or the size of his farm, or the proficiency in farming, or the suitability of his land to match the prospected purchase, or else.

It seems then right to disregard one and each of the above mentioned criteria, but combine them in order to give a multi-criteria approach to decision making. This selection process therefore will take into account many features, both quantitative and qualitative [5, 14], in order to point out finally the "most suitable and efficient" candidate. This, then, will appear as a satisfyer of the prerequisites that Society would expect to be respected before granting pre-emption right in case of more than one candidate.

At this stage, we shall consider attributes pertaining to competing farmers, distinguishing between principal and secondary ones. Each principal attribute will be articulated in secondary ones of various nature. Attribute may be weighted all the same, but more often they show different relevance in people's attributes and therefore get a weight according to the perception of the Society's expectations on land consolidation.

The first level attributes considered here are of diverse nature, such as: similarity (homogeneity) of the adjacent parcels, degree of production efficiency of the pre-emptor (evidence of proficiency), professional training of the farmer (rational management indicator), size of the family, i.e. children available to carry on the job (assurance of long lasting effects of the deal).

The second level attributes are each pertaining to a specific principal attribute, regarding the position of the candidate/s, such as age, higher education degree, years of experience in agriculture, or are qualifying the different plots of land, such as: irrigation potential, its dimension the possibility of using machinery, etc.

To each of these attributes, a specific weight is given according to the particular evaluations of the decision maker or of priviledged testimonials on these issues.

Having assigned attributes and weights to elements of choice, the methodology will step in and a brief discussion is given in the following paragraph, explaining the algorithm to be adopted and the procedures implemented.

All this, however, will allow to be taken into account for "rational", complex decision many aspects, which are relevant for his/her success.

3. THE MODEL

The decisional process adoptes a procedure able to aggregate entirely all the acquired information about the farms and their owners and to build it up through the concept that "more differentiation" is equivalent to "improved decision" [7, 8, 9]. Moreover it measures the acquired information as an isomorphus quantity of the entropy derived from Phisics, that is to say as a measure of the organization of a system.

3.1. The procedure

It works out by the evaluations of the attributes and of actions according to the former. The attributes are divided in two spaces, of first and second level (F and S); from them we consider the product space F×S, on which one point corresponds to the pair (f,s).

On the F set we define an evaluation distribution V(f), which assigns a self evaluation V(fi) to each point fi∈F. The F×S set is generated by assigning a joint evaluation distribution V(f,s) to the product space FS. Provided that V(f)≠0, given a conditional evaluation distribution V(s/f), the joint evaluation distributions V(f,s) are defined in terms of V(f/s):

$$V(f,s) = V(f)V(s/f).$$

In the product space F×S, we define define a measure of the information provided by fi about sp. It consists in changing the evaluation of fi from the priori value V(fi) to the posteriori joint evaluation V(fi,sp). The measure of this change of evaluation follows from the definition: *the amount of joint information I(sp;fi) provided by the evaluation of the attribute represented by sp about the evaluation of the attribute represented by fi, is defined as*

$$I(s_p; f_i) = \log\left[\frac{V(s_p, f_i)}{V(f_i)}\right] = \log V(s_p / f_i)$$

$$= \log V(s_p, f_i) - \log V(f_i). \qquad (1)$$

This result meets perfectly with what our intuition would suggest and matches with the definition provided by Shannon [10]. That information gives also the measure of the constraint between fi and sp and it is equal to zero when the self evaluation is statistically independent from the joint evaluation, V(sp,fi)=V(fi).

Let us consider in the higher-order product space F×S×T, the point (fi,sp,th). Then, we assign a joint evaluation distribution V(th,sp,fi), equal to the evaluation V(sp,fi) assigned to the point (sp,fi) multiplied by the conditional evaluation V(th/spfi).

$$V(t,s,f)=V(f,s)V(t(fs))$$

A joint information for th, given (fi,sp), that we call $I(t_h, s_p; f_i)$, can be defined according to formula (1).

The defined measure of information can be derived from four postulates suggested by our intuition as conditions that should be satisfied by a useful measure of information. They regard the functional form, the summation and independence of information and they are also sufficient to specify the functional form of the desired measure [11].

3.2. The structure of evaluations

The procedure used to point out the evaluations V(fi) (fi∈F) and the conditional evaluations V(sp/fi), V(th/spfi), sp∈S and th∈T, follows the same scheme. Let us consider the monodimensional space of the attributes F=X1. The preference structure of a Decision Maker (DM) on the set F of attributes is modeled by means of an ordinal function, quantifying the relative importance or attractiveness [4, 13] for the DM of the elements of F. The DM:

i) fixes on an axis, in the zero position, a dummy attribute f0 for which the relevance is null and carefully chooses in F the attributes f1 having the least relevance and positions it more or less near the dummy attributes. In this way, a sort of unit of measure useful for the further evaluations.

ii) put into the semi-axis the other relevant attributes fi∈F, i=2,3...m, spacing them out taking into account the relevance of each one with respect to the others and to the unit of measure previously established.

iii) assign to the dummy attribute f0 the real number zero, to the least attribute f1 the real number one and to each element fi a real number π(fi), that we call *rate of differentiation*, which gives the ratio of fi relevance respect to f1 relevance.

In such a way the DM assigns to each attribute a real number going from one (being π(f1)=1) to infinite. The higher the relevance of fi with respect to f1 is, the bigger will be the differentiation between the attributes, and the bigger will be the order in the information system. In such a way an interval scale is obtained on F, by the following condition: ∀ fi, fj∈ F, π(fi) > π(fj) ⇔ fi is ranked before fj.

A greater differentiation brings the decisional process towards an increase in the antientropy: calling V(fi) the rate of evaluation, we put 1/π(fi)=$V(f_i)$, inshort V_i

The nearer V(fi) is to 0, the higher the relevance of the attribute is. V(f1)=1 is the evaluation of the attribute which is judged less relevant in the decision making process. The value V(fi)=0 is an ideal one (*Omega point* [12]), towards which the process proceeds in an high model of complexity [4]. In such a case we have an attribute whose relevance will be so high that the effects of all the other attributes for the decision will be negligible.

Given a first level attribute fi, by the same procedure, the DM, on an axis X2=S, assignes to the conditional attributes sp/fi a rate of differentiation p(sp) and obtaines an interval scale on S. The division of each attributes in subattributes is an increase of information inside the decisional process. This step enables us to reach more complexity but also more order. We are nearer the Omega point compared with the former step and we measure this approach as new entropy of the system. By the conditional evaluation 1/π(sp)=$V(s_p / f_i)$, relating to the attribute fi, the sp joint evaluation is:

$$V(s_p, f_i) = 1/\pi(\mathrm{fi})1/\pi(\mathrm{sp}) =$$
$$V(f_i)V(s_p, f_i) \text{ in short } V_{ip}.$$

The nearer the evaluation Vip is to zero, the more relevant the sub-attribute sp/fi is. We multiply V(fi) by V(sp/fi) taking into account the increase of the approach at the ideal point that the new level adds to the process.

We proceed now, in the space T=X3, for each attribute sp/fi, with the evaluation of the actions. Let $\pi(t_{ip}^h)$ be the rate of differentiation for the h-th action. The higher is the relevance of h-th action with respect to the worst one, the bigger will be the differentiation between them. In such a way we can obtain an interval scale on T. By the conditional evaluation $1/\pi(t_{ip}^h) = V(t^h / f_i, s_p) = V(t_{ip}^h)$ assuming the hypothesis that an alternative evaluated by a relevant attribute and/or relative sub-attribute, increases its desirability, we compute the joint evaluation:

$$V(t_h; s_p f_i) = 1/\pi(V_{ip}) 1/\pi(V_{ip}^h) = V(s_p / f_i) V(t_{ip}^h), \text{in short } V_{ip}^h. \quad (2)$$

3.3. The outranking relation

Now for the information provided by the attribute fi, the sub-attribute sp/fi and the alternative th/spfi, we introduce, respectively, the rates of entropy Ei=log Vi, Eip= log V(sp,fi) and E_{ip}^h=log V(th;spfi). The nearer the evaluations Vi ,Vip, $_{ip}^h$ are to zero, the smaller the value of the entropy is and the more we approach the ideal point through the corresponding rates of resolution: Ri=1/(1-Ei), Rip=1/(1-Eip) and $R_{ip}^h = 1/(1 - E_{ip}^h)$

The nearer the R_{ip}^h position is to the plane (X1,X2), the higher the relevance for the h-th action is. In the space (0,X1,X2,X3), considering also the evaluation of the p-th and i-th attribute, we can say that the shorter the way to reach the point (0,0,0) is, from the R_{ip}^h position, the greater the differentiation inside the decisional process is and the greater the desirability of the action under consideration is.

If we now consider, for the h-th action, all the positions acquired under all the sub-attributes of the i-th first level attribute, we have a polygonal which the more is pressed on the plane (X1,X2), the more the action is preferable according to those attributes. Joining the vertices of the poligonal with the ideal pointW, we obtain a pyramid by which the smaller is its volume L_i^h, the higher is the relevance of the h-th action by the i-th attribute under consideration. The total relevance for the h-th action is obtained multiplying the volumes with respect to all the first level attributes:

$$E^h = \prod_{i=1}^{m} L_i^h . \quad (3)$$

The outranking relation will follow immediately. Given two actions, the h-th and the k-th, we say that the former is less relevant than the latter, if and only if, Eh is bigger than Ek:

$$for \forall a^h, a^k \in A, a^h \succ a^k \Leftrightarrow E^h > E^k . \quad (4)$$

4. THE CASE STUDY

The problem of ranking farms is attacked through a hierarchic procedure, similar to that of other decisional models, which, however, with respect to this one, do not allow the real and exhaustive integration of information [6]. The goal is to obtain the preferable pre-emption with respect to neighbours, on the base of attributes assigneed to them and to their farms. The decisional attributes are subdivided into two levels, see Figure 1. On the first level of attributes F we put the following ones: land feature similarity (SIF), professional qualification (QPR), production efficiency (EFP), family working units (ULF).

At the second level S, let us consider the following division in sub-attributes:

SIF: cropping pattern (SOC), homogeneity (SPI), boundary barriers (SBC) and land size (SES):

QPR: years of activity in agriculture (QLA), high school degree in agriculture (QDP), degree in agricultural sciences (QLR), other diplomas (QLV) and professional qualifications (QQV);

EFP: age (EET), field yields (ERS), mechanization (EMC), irrigation availability (EIR), industrial or tree crops (ECI) and greenhouse or horticultural crops (ECO);

ULF: number of family workers (UNF), active family workers (UFA), family workers qualified as farmers (UCD) and other incomes (UAR).

In the domain of first level criteria the DM

GOAL — I° level ATTRIBUTES — II° level ATTRIBUTES

- Choosing farms
  - Landfeatures similarity
    - Cropping pattern
    - Homogeneity
    - Boundary barriers
    - Land size
  - Professional qualification
    - Years of activity in agriculture
    - High school degree in agriculture
    - Degree in agricultural sciences
    - Other diplomas
    - Other qualifications
  - Production efficiency
    - Age
    - Field yields
    - Mechanization
    - Irrigation
    - Industrial or tree crops
    - Greenhouse or horticultural crops
  - Family working units
    - Number of family workers
    - Active family workers
    - Family workers qualified as farmers
    - Other incomes

Figure 1. Levels of the decisional attributes

chooses first the least important attribute and then he values and differentiates all the others. The expressed rates of differentiation (fi), self evaluation V(fi) and resolution Ri are represented in Table 1.

For example, the EFP attribute has been evaluated of lesser importance, whilst SIF attribute has been estimated as 3.2 times more important.

The same procedure is adopted for each sub-set of attributes. Differentiation rates, subordinate and joint evaluations and resolution rates are shown in Table 2.

The joint evaluations are fundamental in the selection process: for each sub-attribute they are obtained by multiplying the value of those subordinate by that relating to the first level attribute to which it belongs. All that bearing in mind that, by belonging to a sub-attribute related to a strong attribute, its weight in decisional terms is enhanced.

We can say that the least the value of resolution rate, the greatest is the associated preferableness to the attribute. For example, the attribute of least relevance relates to the age (EET), whilst that of greatest relevance to the other incomes (UAR). By the increase of the importance stated for each sub-attributes, the corresponding values of resolution rates decrease, coinciding with a rising differentia-

Table 1. Rates of the first level attributes

		###(fi)	V(fi)	Ri
SIF	f1	3.2	.312	.462
QPR	f2	1.6	.625	.68
EFP	f3	1	1	1
ULF	f4	2.8	.357	.492

Table 2. Rates of the second level attributes

I° lev	Attr.	II° level attributes	mark	*(sp/fi)	V(sp/fi)	V(sp,fi)	Rip
SIF	.312	Cropping pattern	SOC	2.8	.357	.112	.313
		Homogeneity	SPI	2.2	.454	.142	.338
		Boundary barriers	SBC	3.4	.294	.092	.295
		Land size	SES	1	1	.312	.462
QPR	.625	Years of activity in agricult.	QLA	4	.25	.156	.35
		High school degree in agric.	QDP	1	1	.62	.68
		Degree in agricult. sciences	QLR	1.2	.83	.52	.61
		Other diplomas	QLV	1.3	.77	.48	.58
		Professional qualification	QQV	1.5	.67	.42	.53
EFP	1	Age	EET	1	1	1	1
		Field yields	ERS	3.6	.28	.28	.44
		Mechanization	EMC	2.6	.38	.38	.51
		Irrigation	EIR	1.4	.71	.71	.75
		Industrial or tree crops	ECI	1.8	.56	.56	.63
		Greenhouse-horticult. crops	ECO	2.4	.42	.42	.53
ULF	.357	Number family workers	UNF	3	.33	.12	.32
		Active family workers	UFA	1	1	.36	.49
		Family workers as farmers	UCD	2	.50	.178	.37
		Other incomes	UAR	4	.25	.089	.293

tion and informational order in the decisional process. The entropy decreases and we are closer to the ideal point.

The same evaluation procedure is now passed on to the single farms according to each attribute of second level. Having, for istance, chosen the sub-attribute UCD, on its base are stated the preferences with respect to adjacent farms by means of differentiation rates (2.3, 1, 1.8, 1.4). From this stage, subordinate and joint evaluations and resolution rates, Table 3, are derived. The evaluation of each farm gets, therefore, a weighted relevance by the corresponding sub-attribute in consideration.

We can then say that farm F4, according to the attribute UAR has the highest preferableness (.22), while low preferableness (1) relate, for example, to farm F1 according to the attribute EET. Through the preferableness shown by each farm, according to the various sub-attributes, it is calculated the global preferableness associated to the first level attributes, see Table 4 in the first four rows.

As comment of these partial results, we can say that the highest preferableness relates to farm F4 according to attribute ULF, while the lowest to farm F2, according to attribute EFP. By multiplying amongst them the results from primary attributes, we obtain the total values of absolute preferableness associated to each farm (last row of Table 4). The outranking relation yields the following ranking of preference, from the farm with highest pre-emption right to the lowest one.

$$F4 \succ F3 \succ F1 \succ F2 .$$

Table 3. Rates related to the farms according to the sub-attributes

		F	A		R	M		S					
Attr.	Sbattr	F1			F2			F3			F4		
fi	sip	π(th)	V_{ip}^{h}	R_{ip}^{h}	π(th)	$^{h}_{ip}$	R_{ip}^{h}	π(th)	$^{h}_{ip}$	R_{ip}^{h}	π(th)	$^{h}_{ip}$	R_{ip}^{h}
SIF	SOC	3.2	.11	.23	1.3	.27	.30	1.5	.24	.28	1	.36	.31
	SPI	2.3	.20	.26	1	.45	.34	2.7	.17	.25	3.5	.13	.24
	SBC	1	.29	.29	1.4	.21	.27	1.6	.18	.26	1.9	.15	.25
	SES	3.1	.32	.30	2.6	.38	.32	1	1	.46	1.8	.56	.36
QPR	QLA	3.1	.08	.25	2.4	.10	.27	1.8	.14	.29	1	.25	.35
	QDP	3	.33	.39	1	1	.68	1	1	.68	1	1	.68
	QLR	1	.83	.61	4	.21	.33	4	.21	.33	1	.83	.60
	QLV	1	.77	.58	2	.38	.41	2.5	.31	.38	2	.38	.41
	QQV	1	.67	.53	2.4	.28	.36	3	.22	.34	2	.33	.40
EFP	EET	1	1	1	1.2	.83	.85	1.8	.56	.63	2	.5	.59
	ERS	1.6	.17	.36	2.3	.12	.32	1	.28	.44	2.9	.10	.30
	EMC	1.3	.30	.45	1.7	.23	.40	1	.38	.51	2.6	.15	.34
	EIR	3	.24	.41	2.4	.30	.45	1.6	.45	.55	1	.71	.75
	ECI	2.3	.24	.41	2.5	.22	.40	1.5	.37	.50	1	.56	.63
	ECO	2	.21	.39	1	.42	.53	2.4	.17	.36	2.5	.17	.36
ULF	UNF	2.3	1.4	.25	1	.33	.32	1.4	.24	.29	1.7	.20	.27
	UFA	1	1	.49	1.4	.71	.42	1.5	.67	.41	1.9	.53	.37
	UCD	2.3	.22	.28	1	.50	.37	1.8	28	.30	1.4	.36	.33
	UAR	2.7	.09	.23	1	.25	.29	2.1	.12	.24	3.1	.08	.22

Table 4. Preferences related to the farms according to first level attributes

	F A R M S			
I° ATTRIBUTES	F1	F2	F3	F4
SIF	1.08x 10E-02	1.142	1.65	1.29
QPR	3.22	2.19	2.03	2.35
EFP	3.45	4.74	3.23	3.18
ULF	.545	.703	.578	.529
Eh x 10E-08	6.573	8.369	6.251	5.128

5. CONCLUSIONS

The results given previously have yielded the output expected as they allowed a ranking of the competing neighbours. This ranking sums up all the possible evaluations which have been inserted into the decisional process.

The procedure here adopted proves suitable for assemblying quite different criteria, adopted to reach the evaluation of the most "suitable and efficient" candidate. The methodology followed and presented here, as regard to the weighting of the attributes, is based on a graphic procedure, easily handled by the DM. The aggregation of information which step-wise is obtained by the reduction of entropy allows to assess the preferableness of the farmer.

The ideal point concept allows us to understand the preferableness expressed both on the attributes and/or on the alternatives. Therefore the obtained solution also and its structure appear clear cut and can be under close scrutiny.

The resolution rates are indexes of great interest: by integrating through them the most heterogeneous information, they allow for a complete characterization of the farm also through its manager and this should be duly considered in the Farm Appraisal methodologies.

As for the selection of the "most suitable and efficient" farmer, we experienced that even by considering both farmers and farms, at the end, a definite preference was pointed out even amongst fairly similar competitors.

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