Modeling the process of operational decision-making in agriculture: a bounded rationality approach

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1 Les enjeux scientifiques et socio-économiques

Internationalization of markets, shifts in consumer demands and requirements, rapid evolution of technologies, and change in political context are among the recently emerging factors that make competitiveness much harder to achieve and maintain in the agricultural production industry. As a production manager the farmer makes decision about the timing, combination and implementation of technical operations (tilling, planting, fertilizing, irrigating, spraying, harvesting, feeding animals, etc.) in hope of achieving his objectives. The farming business is uncertain because the outputs of operations are subject to hardly predictable events of nature (weather, disease, etc.) and because it depends on changing and uncertain economic factors (market demand, fluctuation of prices, interest rate, public support etc.) for which information can be limited or unavailable. In such a context, the complex interaction between natural and man-controlled processes is at the very heart of agricultural production. The amount and quality of output that result from a given bundle of inputs cannot be predicted with certainty, i.e., the production function is stochastic because uncontrollable elements, such as weather, play a fundamental role in agricultural production. Moreover their effects are heightened by the fact that time itself plays a particularly important role because long production lags are dictated by the biological processes that underlie the production of crops and the growth of animals. Price uncertainty is also a standard attribute of farming activities. Because of the biological production lags, production decisions have to be made far in advance of realizing the final product, so that the market price for the output is typically not known at the time these decisions have to be made. Although there exists different financial or insurance tools for covering against these multiple (correlated or not) sources of uncertainties, the burden of this unstable context and highly complex decision problem is still on the shoulders of the farmers that will need therefore enhanced management ability.

The performances of farms operating in similar physical and economic environments are often very different (Solano et al. 2006). Research shows that the difference is mainly due to the farm manager's decision-making aptitude, ability to manage uncertainties, and ability to properly weigh up a wide range of factors and to adapt to changes. Good management depends essentially on the manager's technical, conceptual and diagnostic skills. The production performance is critically dependent on the ability of the farm manager to deal with the right problems and opportunities at the right moment in the right way. Farmers always had to manage uncertainties and adapt to changes. However, agricultural practices and knowledge were developed to deal with uncertainties within the limited range in which they usually occurred. By far the majority of farm managers make decisions and implement them on the basis of their intuition or tacit knowledge, which is probably the result of years of experience of outcomes of past decisions, and interactions with colleagues and advisors. Actually they seem to have a decision-making behavior that is both plan-based and responsive to the ongoing situation. Indeed, farmers have limited information about the different sources of uncertainties, and this aspect considerably affects how farmers make decisions. Yet, little attention has been given to the understanding of farmers' cognitive ability as the basic determinant of their managerial ability for strategic and day to day decisions. The increasing complexity of operational decision-making in agriculture is a source of challenging questions to research in decision and management sciences. What kinds of practical reasoning does a manager perform and what are the distinguishing characteristics of the pieces of information used in judging what to do? How can decision be made quickly and with almost no calculation? Enhanced analysis instruments are needed to study management behavior in different scenarios, and to identify possible flaws, vulnerability and adaptation possibilities. It is our belief that investigating these questions may lead to descriptive approaches leading to improvements of farmer's management ability.

2 La (les) question(s) de recherche

The sequential decision problem at the core of farm production management is primarily governed by the exploitation of practical knowledge about how to handle a production process toward the achievement of some general objectives (essentially production performance target). This knowledge can be seen as a set of crisp constraints that restrict significantly at any time the actions that are deemed relevant to the objectives and are feasible given the actual conditions (Martin-Clouaire & Rellier 2009, 2011). Basically these constraints define a flexible plan that specifies temporal and procedural organization of activities, state-dependant conditions of their pertinence and feasibility, and resource requirements (see for instance Martin et al. 2011; Rellier et al. 2011;

Ripoche et al. 2011). At any time the interpretation of such a plan determines what is permitted according to the plan and what is possible given the limitations of resources (labor, machinery etc.). Given the flexibility of the plan this constraint satisfaction phase yields several sets of actions. Each set is a candidate solution. The thesis work is focused on the problem of choosing the preferable solution to execute among the candidate ones. This kind of choice problem has to be repeated as often as required by the occurrence of disruptive events that interrupt the execution process (typically at least once a day).

The central question of the thesis proposal can be stated as: how is a farm manager cognitively approaching decisions and how is he integrating constraints, desires and judgment. The central question induces two types of investigation to:

- categorize and represent the heterogeneous types of information taken into account in the decision-making process, and determine how such relevant information can be dynamically gathered or constructed at every decision stage;
- formalize and model the decision process by which such information can be manipulated and combined. Instantiated cases of this process should bear strong resemblance with the choice procedures observed or imaginable in real situations.

In agriculture operational production management has to deal with: (1) a series of interdependent decisions and/or actions (today's choices have to be made in coherence with those made previously); (2) constantly changing situations; (3) shifting goals and preferences. The potentially relevant pieces of information that drive the decision process need to be extracted or even constructed for every choice task. That is, farmers need to get preferences and beliefs on the spot when needed, instead of having known, well-defined, and stable ones. In order to be able to understand differences between management behaviors one has first to indentify the types of information invoked, their role in the decision process and the way they are dynamically acquired.

The choice process involves information sources that induce a restriction of the set of candidate solutions (for instance, non urgent candidate solutions can be discarded if others are urgent). Contrastingly, other factors taken into account in the choice (e.g. cost or expected efficiency) influence the result by modifying the strength of preference of a particular solution over the others. The choice process amounts to a multifactorial evaluation of arguments against or in favor of the candidate solution. Of course, uncertainty about the actual state (due to observation difficulties) or future events (weather essentially) may affect the farmer's choice process, which as usual, involves trading-off between what ought to be (goals) and what can be (belief). The decision process is also responsible of directing or maintaining the continuous flow of management behavior toward overall production objectives (it is not solely a set of independent episodes involving choices dilemmas). To be faithful to the reality, the choice process in our model has to involve little processing in order to be compatible with the paucity of information and the fast pace of decision-making observed in farmers' practices.

3 Le contexte méthodologique choisi et les développements envisagés

Traditional studies of decision-making in economics, operations research and artificial intelligence have tended to view decision-maker as possessing supernatural powers of reason with limitless mental resources and full, information to apply a particular principle of rationality. Indeed perfect rationality is a crucial assumption in economics that assume agents make their decisions coherently with the utility maximization doctrine. Actually, Expected Utility (EU) theory remains the dominant approach for modeling risky decision making and is still the paradigm of reference in decision making. This framework addresses decision problems in which the decision setting does not change (goals do not shift or need not be redefined) and the decision options and consequences are completely known or assumed so. Despite its normative appeal, the EU framework has come under intense scrutiny because of its inability to describe some features of individual behaviour under risk as shown by several experiments and empirical observations. Several studies have proposed more general theoretical frameworks such as the Kahneman and Tversky's prospect theory (1992) that distinguishes between preferences in the gain and in the loss domains and assumes that the objective function is non linear in probability. However all these theories adhere to the paradigm of perfect rational decision-maker. Moreover, the EU model has also been criticized on the framing aspect: the difficulty of getting the options, probability, and utility values.

In a complex and uncertain world, humans make decisions under the constraints of limited knowledge and cognitive processing resources. Yet classical models of rational decision making ignore the importance of these real constraints and instead assume agents with perfect information and unlimited time. In his seminal work, Herbert Simon (Simon 1976) challenged this view with his notion of "bounded rationality" He introduced the notion of *satisficing,* contending that decision-makers deal with real-world complexity by using procedures that find ''good enough'' answers to questions when best answers cannot be obtained. There is general agreement among psychologists that there are limits to our processing ability. Many approaches to the study of judgment have emphasized simplicity and limited computation in accounting for agents' behavior (Cozic 2008; Mongin 1986; Laville 1998; Selten 1998; Walliser 2008). Following Simon, a behavioral science framework, called

Naturalistic Decision Making (NDM) (Klein et al., 1993) has investigated how experienced people make decisions to solve problems in real-world settings in dynamic, uncertain, fast-paced environments. It focuses on the mental processes of information processing and reasoning. Gigerenzer and coll. (Todd & Gigerenzer 2000) have studied the way the human mind can take advantage of the structure of information in the environment to arrive at reasonable decisions using 'fast and frugal' reasoning (for instance, considering only the single most valid cue that discriminates between options and ignoring all the others). The entire point of using heuristics is that it is extremely simple so that minimal cognitive processing is required.

The issue of making decision on the basis of arguments that either support or discard the candidate solutions has lately received a renewed attention in disciplines such as artificial intelligence (Dubois & Prade 2008) and cognitive psychology (Raufaste & Vautier 2008). The idea has also been explored by Tversky and Kahneman (1992) in their prospect theory (where the importance of positive and negative aspects are measured separately) but qualitative approaches (Dubois & Prade 2009) seem more appropriate to comply with the meagerness of information available at decision time and the limited processing capacity that can be engaged by the farm managers.

The structure and processes that govern farm-level decision-making (Rougoor et al. 1998, Gray et al. 2009) are also of concern in disciplines such as farm management (Nuthall 2011) and agricultural production economics (Chavas et al. 2010), especially through their contribution to the study of risk, that is, the effect of uncertainty on production decision-making and resulting performance. The analysis in this area includes examination of sources and magnitudes of risk and consideration and measurement of risk attitudes for producers. Traditionally, in economics, emphasis is placed on the criteria by which a choice is made rather than the process of making the choice, which lies at the core at in this proposal. In the past fifteen years, some research works, inspired in particular by behavioral economics, cognitive sciences and bounded rationality (Öhlmer et al. 1998; McCown 2005, 2012; McCown et al. 2012) renewed interest in the study of practical decision problems in operating a farm. The thesis proposal goes one step further by looking into the decision-making process so as to deepen the investigation of managerial practices.

Proposed development

The investigation work will aim at carrying out a descriptive study enabling to get better insight on the farmers' cognitive behavior in making operational decisions. In order to make possible an experimental investigation of such behavior considered as a research object the thesis work should ultimately provide a general and implemented model of the decision process, hopefully covering the variety of decision-making behaviors identified.

The main stages of the project include:

- Literature review and refinement of research questions;
- Elaboration of examples of operational decision-making in agriculture. Done in collaboration with agronomists, domain experts and farmers;
- Identification, categorization and structuring of potential factors (individual or in combination) influencing the selection or rejection of any action;
- Framing of the iterative agricultural decision problem to insure than the identified factors involved in the decision process can effectively be derived at every decision-stage from the state-based information typically accessible to the decision maker. The cognitive limitations of the decision-makers may restrict the accessibility. This stage and the previous one are intertwined and involve the kind of conceptual modeling at work in any systems engineering project;
- Formalizing and implementing the decision procedure. The above-mentioned body of philosophical and theoretical tools in bounded-rationality, qualitative decision, cognitive psychology and behavioral economics is central in this stage development;
- Examination of the empirical validity of the proposed model by confrontation to available examples;
- Writing of the thesis and at least two papers: one targeting the farm management community, and one aiming at the artificial intelligence and behavioral economics communities.

4 Les pré-requis pour le candidat

- Required degree: Research master (or equivalent degree) from an agronomic engineering school
- Familiar with modeling techniques (conceptual, formal and computational)
- Appreciated competencies: bounded rationality, artificial intelligence, cognitive economics, behavioral economics, farm management

An internship project (master-2 level) is proposed by the supervisors as a preliminary stage of the thesis work. The project actually is a follow-up of the one realized last year on the survey of bounded rationality approaches.

5 Les perspectives professionnelles pour le doctorant

Enseignant-chercheur ou chercheur
Ingénieur dans un organisme ou société de conseil en gestion de production

6 Les propositions de noms pour le comité de thèse

J.-P. Amigues (INRA-SAE2, Toulouse) - Economics
H. Prade (IRIT, Univ. Toulouse 3) - Artificial intelligence
E. Raufaste (CLLE-LTC, Univ. Toulouse 2) - Cognitive psychology
M. Tchamitchian (INRA-SAD, Avignon) – Agronomy and farming systems

7 Le partenariat scientifique et industriel dans lequel s'inscrit le travail

At least one senior farming system researcher will be associated to the project, contributing with his/her expertise on a production domain and his/her network in the professional community.

8 Les publications du laboratoire d'accueil sur le sujet

Brunette M., Cabantous L., Couture S., Stenger A. (2012) The Impact of Governmental assistance on Insurance Demand under Ambiguity: A Theoretical Model and an Experimental Test», à paraître dans Theory and Decision. DOI: 10.1007/s11238-012-9321-8.

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9 Bibliographie

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Laville F. (1998) Modélisations de la rationalité limitée : de quels outils dispose-t-on ? Revue Economique, 49(2), 335-365.

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Todd P., Gigerenzer G. (2000) Précis of Simple heuristics that make us smart. Behavioral and Brain Sciences, 23, 727–780.

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