A recursive dynamic optimization model to assess the impact of unexpected changes on suckler cow farms

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Abstract: *Suckler cow farms are susceptible to unexpected changes of weather, market or regulation conditions which may threaten farm sustainability. We propose an original framework to gauge the resilience and vulnerability of farm to unexpected changes conditional to optimal adjustments decisions. A dynamic recursive bioeconomic optimisation model is developed with a detailed biotechnical specification providing numerous sources of flexibility. The model is calibrated to represent different systems for Charolais production in France. Validation involved comparing model outcomes to actual farming practices and checking that model sensitivity to changes is consistent. An example of assessment of forage production variation impacts on a farm producing young bulls and grain and forage crops is proposed. This framework can be extended to simulate different kind of changes to help defining mitigation strategies in a changing environment.*

Keywords: *unexpected changes, recursive optimization model, suckler cow farm, flexibility*

Introduction

The less vulnerable the farm is to different sources of changes, the more sustainable the farm is supposed to be. The French suckler cow farms may be vulnerable to changes regarding climate, beef market or public support. Sources of flexibility such as the possibility to produce different animals, and to use different sources and quantities of feed supply, allow farmers to adapt their production system to changes in order to generate additional income or to avoid losses. These adjustments decisions might have consequences not only on present outcomes but also on future ones. The problem is then to assess not only what sources of flexibility are used to face changes, but also how important the dynamics of the system are modified following the change (i.e. its resilience) and how the farmer's profits are affected (i.e. its vulnerability). These issues are to be considered conditional to the exogenous changes which occurred and to farmers' behaviour. A recursive dynamic optimisation farm model is developed. As an example, an application of this framework corresponding to the simulation of exceptional temporary pasture production variations is given.

Model description

Modelling farmer's behaviour: As economic agents, farmers react strategically and with foresight by considering outcomes that might result from their behaviour. Our model assumes that farmers make decisions to maximise their expected utility of profit Z (eq.1) over a 6-year planning horizon. We suppose inter-temporal preferences which favour present income by the mean of a discount factor *r* and regular income through year by adding a parameter *α* to account for the elasticity of inter-temporal substitution

$$\text{Max}_{\{D\}} \qquad Z=\sum_{t=1}^{6}\left(\frac{1}{1+r}^{t-1}\times\frac{1}{1-\alpha}\Pi_t^{1-\alpha}\right)+\frac{1}{1+r}^{T}\times\frac{1}{1-\alpha}VS^{1-\alpha} \qquad \text{(eq. 1)}$$

With: {D} the set of decision variables, t={1…6} the years of the planning horizon

It is assumed that farmers revise their decisions when new information becomes available. However they neither anticipate that these unexpected events may occur nor that they will be able to adjust their decisions. This is modelled through a recursive sequence of multi-periodic optimisations reinitialised after each by incorporating additional information. This information is composed of the dynamic variables values at the end of the first year of the previous optimisation and with updated information regarding price, weather and regulations. This sequence covers the 15 years period of the simulation.

Modelling production system: The production system consists in beef cattle based on a suckler cow herd with grain and forage crop production. Twelve animal classes are introduced to represent the different possible kind of animals within the herd. Animals remain in a class one year, and then move toward the next class according to a transition matrix. Classes are described by two dynamic variables: the number of animals and their average live weight which is allowed to vary within a 10% range. These dynamics can be controlled by monthly decisions predominantly related to animal sales and animal diet. Concerning crop production, five feeds (grazed grass, hay, silage maize, barley grains, straw) can be produced from four different crop productions. They are characterized by parameters of qualities and variables of quantities. Feed quantities are dynamic variables as the quantity stored depends on each period’s balance between previous stock, and decisions of: produce consumed by the herd, produce purchased and produce sold. Farm structural characteristics such as housing and farm storage capacity, labour and land availability constrain the production system.

Modelling profit: Profit is defined as the difference between on the one hand sales and agricultural premia and on the other hand variable costs linked to crops and herd production.

Data and Calibration: Data used to parameterise the multi-periodic model come first from coupled biotechnical sub-models: a pasture growth model (Jouven et al., 2006) and an animal growth model to simulate average animal live weight and animal need based on INRA (2007) and Garcia and Agabriel (2007). Secondly, a panel database comprising of 87 Charolais suckler-cow production systems with information from the 1999-2006 period and created by the Livestock Economic Unit of INRA-Theix (Veysset et al., 2005) was used to calibrate animal sub-models, economic data as well as average farm structural characteristics for different systems of production.

Validation procedure: The model is validated to our objectives which are: (1) to provide a model flexible enough to enable the model to adapt to changes, (2) to reproduce correctly farmer’s decisions and farm dynamics when stable and when challenged by unexpected changes. First we compare the range of production and adjustments possible in our model to the one observed in the data base and to propositions in the literature. Second, for different structural characteristics, we check that production decisions during periods of stability are close to that observed in the database for the average year and average farm. Finally, we test the model’s sensitivity to changes to assess if the reactions observed in the model are coherent with scientific knowledge and past observations.

Example of application

We apply our model to a farm producing young bulls with a 1.4 stocking rate. We simulate two exceptional temporary changes of forage productions yields (maize silage and pasture) in between average productions yields years: a catastrophic one (-30%) and a very good one (+30%). Main results are that adjustments of feed supply and consequently of animal diets are preferred to an adjustment of animal number and live weight. Variations of forage production are then compensated by opposite variations of grain consumption which in turn modify grain sales. Second gross margin variation following forage production losses corresponds to 9% of the gross margin with a maximum of 5% loss for year 3 and necessitate three years to return to equilibrium. Eventually, total profit surplus (7%) following a very good forage production year does not fully compensate bad production years.

Conclusion and perspectives

We developed a bio-economic model which has the ability to offer both detailed production specifications to give more production flexibility and an economic representation of farmer behaviour that takes into account their expectations. By simulating appropriate scenarios of unexpected events, vulnerabilities can be exposed. This can help policy makers (e.g., for insurance and compensation indemnification) and farmers to build mitigation strategies to enhance farm sustainability in a changing environment.

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