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A dynamic bio-economic model to simulate optimal adjustments of suckler cow farm management to production and market shocks in France

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ABSTRACT

Tactical adjustments to seasonal weather conditions and beef price may generate additional income or avoid losses in French beef cattle farms. Due to the length of the suckler cow production cycle, adjustment decisions may impact not only on current production and profit but also on future farm outcomes. To better understand the consequences of shocks and subsequent production adjustments on the evolution of farm earnings and production over time, we built a dynamic recursive bio-economic farm model. Our model introduced simultaneously the possibility of adjusting herd size and herd composition, diet composition and diet energy content, as well as crop rotation, haymaking and feed stocks, taking into account both their short- and long-term consequences. An application is provided to test impacts of crop yield and beef price shocks of different intensities. Main simulated adjustments to face unfavourable weather shocks are (1) purchased feed in order to maintain animal production objectives, and (2) area of pasture harvested for haymaking. Very severe beef price shocks induce forced sales. Weather shocks affect farm net profit not only of the current year but also of the following years. Profit losses caused by unfavourable weather conditions are not compensated by gains in favourable ones and this differential is amplified when intensity of shocks rises.

1. Introduction

Suckler cow systems which consist in raising calves with their mother's milk in order to produce meat are an important feature of French agriculture. The 4.3 million French suckler cows indeed represent more than one-third of all European suckler cows and supply around 60% of the beef production in France. They also participate in rural development, as few economic alternatives to livestock farming exist in these areas and they help in maintaining large areas under grassland which favours biodiversity and limits pollution and erosion (Le Goffe, 2003). However, these farms rely on pasture production which is very sensitive to weather conditions (Gateau et al., 2006) and they sell mostly only beef, which makes their income fluctuate with beef market conditions. Risk management in suckler cow farms is not only of interest for farmers but also for policy makers who support suckler cow farmers: a French fund compensates farmers in the event of agricultural calamities such as drought on forage crops (Boyer, 2008) and the common agricultural policy (CAP) beef market organisation ensures minimum prices. However, policy makers are thinking about reforming their support to farmers to improve risk management in agriculture. Risk management encompasses an *ex ante* stage to mitigate risk exposure and an *ex post* stage to limit impacts of unfavourable shocks or to take advantage of new opportunities. Gauging on-farm capacity to cope with risks can help farmers (Pannell et al., 2000) and policy makers to set up a more efficient risk management framework. This paper focuses on the way suckler cow farmers can adjust their production system to manage *ex post* beef prices and weather risks in order to avoid losses or to generate additional income.

Numerous sources of flexibility in production management can help farmers to cope, *ex post*, with weather and market shocks. Firstly, in France few farmers are tied by contracts to sell their animals, they can thus decide to adjust the ages and body conditions of animals sold to current market opportunities and feed supply availabilities. Secondly, farmers can adjust animal diet composition and alternate between periods of underfeeding and periods of live weight recovery (see Blanc et al., 2006, for adaptive capacity of cows) or accelerated growth (see Hoch et al., 2003, for compensatory growth of young animals). Possibilities to adjust haymaking as well as opportunities to sell or purchase crop products also add some margins of manoeuvre. In such an entangled production system where the different enterprises are interlinked and where current decisions can have consequences on the production system for years to come, modelling offers a comprehensive way to under-

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stand the workings of this complex system and to simulate impacts of weather and beef price shocks.

Bio-economic models detail biotechnical specifications and simulate farmer decisions assuming that they make their decisions in order to optimise their objective function (see Janssen and Van Ittersum, 2007, for a review). Static bio-economic livestock models (Veysset et al., 2005a; Crosson et al., 2005; Havlík et al., 2005; Matthews et al., 2006) do not give the opportunity to study farm responses outside an optimal steady state. Dynamic programming methods are necessary to represent sequential decision-making processes to permit progressive adjustment in a changing environment. Some dynamic bio-economic livestock models have been built to assess impacts of weather (Olson and Mikesell, 1988; Kingwell et al., 1993; Jacquet and Pluvinage, 1997; Kobayashi et al., 2007) or price risks (Lambert 1989; Ridier and Jacquet, 2002) on livestock farms. However, few of them (except Kingwell, 1994) simulate shock impacts when taking simultaneously into account the possibility of adjusting animal live weight, herd size, crop product stocks and land use. To our best knowledge, none of them simulates the consequences of all these production adjustments in both the short (month) and the long (several years) runs. This can be explained, as discussed in Blanco and Flichman (2002), by the programming methods used in these models, namely stochastic dynamic programming or discrete stochastic programming. They are limited, respectively, by the number of dynamic variables or by the number of periods where decisions can be readjusted. Model size indeed increases rapidly when variables or stages increase. To overcome these limitations, Barbier and Bergeron (1999) and Iglesias et al. (2003) adopted a dynamic recursive framework which consists of a sequence of deterministic multi-periodic models. Recursive structure offers the possibility of assessing farm evolution with numerous dynamic variables while keeping model size tractable. It also provides a way of introducing unexpected shocks.

The purpose of this paper is to develop a suckler cow farm model to assess how farmers can use the different sources of adjustments in a complementary way to face shocks of different intensities and how these shocks impact on their production and income in both the short and long runs.

The remainder of this article is organised as follows: we first describe the model specification and the data used. Then, simulated results of beef price and crop yield shocks of various intensities are exposed. Before concluding, implications of our modelling choices and application results are discussed.

2. Model description

2.1. Model overview

Our model aims at simulating monthly production decisions of suckler cow farmers and the monthly evolution of their production system (technical and economic) in a risky environment. The production system modelled consists of beef cattle production based on a suckler cow herd, combined with grain and forage crop production (Fig. 1). It is parameterised to represent suckler cow farms located in the Northern part of the Massif Central which is the most important production area of the Charolais breed in France. A panel dataset of 65 farms extracted from the 'Charolais farms' database of the INRA Research Unit of Livestock Economics over the period 2000–2006 (Veysset et al., 2005b) has allowed us to have detailed technical and economic information about these farms.

To represent herd dynamics, the herd is divided into various annual animal classes consisting of "representative" animals. Animals from the different classes can be sold almost all year round and can receive a large range of diets (animal live weights are linear functions of their energy intakes). Live weight variations are however bounded in order to avoid repercussion on animal health and on animal reproduction performance. Crop products stored (feed and litter) come from on-farm crop production that can partly be completed by purchased products. These stocks can be either sold or used to meet herd needs. On-farm crop production is controlled by land allocation and haymaking (number of cuts and area harvested) decisions. Land, building and labour are fixed constraints. Interaction between herd and land use are not explicitly modelled.

To represent farmer decision making, we assume that farmers plan their production decisions to maximise their utility of net profit over a 5-year planning horizon. Each month, the 5-year decision plan can be revised based on the observed realisation of beef price and weather risks. Technically, this is modelled thanks to a recursive sequence of multi-periodic optimisations. Each optimisation is reinitialised by incorporating dynamic variable values of the previous optimisation and updated market, weather or CAP conditions. When the farm environment is stable, farm dynamics converge toward equilibrium.

For a 5-year simulation, our model resolved by the non-linear programming solver *CONOPT* run in *Gams* (GAMS development Corporation, 1217 Potomac Street W; Washington, DC 20007, USA) generates almost 10,000 outputs related to profit and costs, to animal and crop productions.

In the following section, the production system and farmer decision problems are further detailed.

2.2. Animal production

To cover the range of animal production in the Charolais production area, 12 annual animal classes characterised by sex (male, female or castrated male), age (from new born to mature) and production objective (fattening or storage) are introduced in the model (Table 1). Classes, indexed by *a*, are described by two endogenous dynamic variables: the number of animals and their average live weight (24 state variables in total). Herd management consists in controlling those dynamics thanks to the (1) monthly control of animal sales, (2) monthly choice of animal diet composition and diet energy content, (3) annual number of mated cows, and (4) annual fattening objectives.

The number of animals in each class is initialised for the first month of the planning horizon. Then intra year dynamics are defined by the motion function *f*. For each month *p* of year *t* and animal class *a*, this function draws the balance between past number of animals (*NB*), sales decisions (*ASold*) and mortality (*mort*) (Eq. (1)). Since animals are seldom purchased in our database, we do not introduce the possibility of buying animals

$$NB_{a,t,p} = f_{p-1}(\cdot) = NB_{a,t,p-1} \times (1 - mort_{a,t,p-1}) - ASold_{a,t,p-1} \quad (1)$$

At the beginning of each following year, in April, an animal may change from one class to another because of natural ageing process (the number of 1-year old heifers at the end of a year becomes the initial number of 2-year old heifers the following year), because of reproduction objectives (calf numbers depend on the number of mated cows) and because of fattening objectives. The model can choose for instance to convert part of the number of 2-year old heifers into fat heifers (Eq. (2)) and the remaining part into primiparous cows (Eq. (3)). Primiparous cows are females calving for the first time (they are called multiparous after the following pregnancy). They are differentiated from multiparous cows because they are still growing and have different needs. In the studied area, females calve for the first time at 3-year old and then once a year in winter. Multiparous cows do not undergo an ageing process in our model (they correspond to only one animal class); consequently, a