Measuring the Effects of Alternative Support Policy Instruments on Beef Supply

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Abstract.

The European Union beef market regulation is largely influenced by the Common Agricultural Policy (CAP). With the 1992 CAP reform, there was a partial shift by the EU from product price support to a more direct form of income support by way of direct payments. For beef there was a move to direct payments on intermediate products which was essentially a direct payment for the possession of various categories of animals and these were linked to a land resource base. The Agenda 2000 reform consists in a further price decrease associated with an increase in direct payments.

The objective of this paper is to assess how the behaviour of beef producers is sensitive to changes in production prices and to changes in premiums. The analysis relies on an analytical framework which allows to take into account the dynamic feature of beef production and the subsidies provided by the Common Agricultural Policy. We studys how the beef supply response is modified when various exogenous variables like prices or premiums are changed. The application focuses on the dynamics of beef supply response in the French beef sector.

Keys words : beef supply, dynamic modelling, expectations, direct payments, Common Agricultural Policy

JEL codes

C61, Q12, Q18

1. Introduction

The European Union (EU) plays an important role on the international exchanges of beef both in imports and exports. Its main export areas are the East Europe, the Near East and the North Africa, while its main import areas are countries from the MERCOSUR and from the ACP areas with which preferential exchanges exist (Lomé agreement). However, since the early 1980s, the EU beef market is structurally over target and, thus, is largely dependent of trade with countries outside the EU. Until 1995, exports were made with the help of subsidies. However, due to the 1993 GATT agreements, this system must be progressively removed. A new challenge for the EU is to find a way of opening up new export outlets without subsidies.

Moreover, the EU beef market regulation is largely influenced by the Common Agricultural Policy (CAP). One of the objectives identified by the EU is an increase of competitiveness internally and externally. The 1992 reform was an attempt to improve market balance by reducing intervention prices and by increasing direct payments with an introduction of a ceiling on the number of animals eligible for support. These changes represented a switch in the nature of the support provided rather than a reduction in its amount. For cereals a payment per tonne was converted to a land based area aid using historical yields. For beef there was a move to direct payments on intermediate products which was essentially based on the possession of various categories of animals with a maximal amount of livestock units per forage areas. The main premiums for beef producers are the suckler cow premium and the special premiums for male animals.

However, particularly because of the disruption caused by consumer concerns over BSE, the EU beef market remains over target and the Commission projections indicated a further accumulation of stocks up to 2005 if the 1992 agricultural policy was maintained. Hence, the CAP reform within the Agenda 2000 consists in a further price decrease by 20 % over 3 years associated with an increase in direct payments. From 200/01 and over 3 years, the first special beef premium will be increased of 55 % while the increase of the second one is of 38% as for the suckler cow premium increase. This new price reduction is defended as a way of opening up new export outlets without subsidies and rebalancing internal consumption to the benefit of beef. However, the income support mechanism remains partly based on product price and mainly on possession of animals.

This contribution focuses on the dynamics of beef supply response in the European beef sector. The objective of this paper is to provide a model of beef supply response within a dynamic microeconomic framework. The aim of this model is the understanding of cattleman decisions and the assessment of how the behaviour of beef producers is sensitive to changes in production prices and to changes in premiums. In particular, the paper studies how the choice of keeping or slaughtering an animal (the beef supply response) is modified when previous exogenous variables are changed. This is done by considering the cattle herd as a capital good. Changes in the capital stock represent investment (or disinvestment) decisions that are influenced by market prices and compensatory payments. Furthermore, as a cattle become older, its capital value is expected to change, implying that investment decisions in the cattle herd are different for each age category. On this basis, a dynamic model of the cattle's herd size and age structure is developed by considering explicitly the influence of market prices on culling and replacement decisions for each age category in the cattle herd. In particular, biological information concerning the dynamics of the cattle population is exploited in the specification of the model. It is shown to play a crucial role in the economic adjustments of beef production to changes in relative prices. The biological structure of the cattle and the fact that cattleman makes his production decisions on the basis of expected prices are explicitly introduced. Thus, within this modelling, dynamic relationships are derived from optimising behaviour of producers over time and not simply from *ad hoc* considerations.

The approach taken in this paper to analysis beef supply is as follows. In section 2, the particular features of cattle raising are discussed and some simplifying assumptions are introduced. The dynamic microeconomic model, based on the behaviour of individuals whose objective is to maximise expected profits over their entire work-life horizon and allowing both different types of animals on farm and the existence of premiums, is presented. In section 3, this profit function is maximised by dynamic programming methods to obtain the relevant behavioural relations which determine the econometric specification. The resulting empirical equations implied by the model are described. Section 4 then discusses the farm level panel dataset for France constructed for the period 1995-1997, the estimation methods and reports the estimation results. Section 5 concludes.

2. The theoretical framework

2.1. Basic assumptions

In this section, we give a brief description of the options open to the cattleman during each period in which optimising decisions must be taken. Some specific assumptions depend on model specification, data availability and estimation needs. To simplify, we do not consider either the market for feed or the milk sector explicitly.

We distinguish among different categories of animals, because they enter as different decision variables in the maximisation problem: heifers, suckling cows, male calves and male cattle. The distinction between these different categories of animals allows us to integrate various subsidies provided by the Common Agricultural Policy (CAP). We assume that the cattleman does not sell female calves. All female calves are grown to heifers, while male calves can be sold or grown to male cattle. Given data availability, it is necessary to assume that, after twelve months of age, calves are considered heifers or male cattle.

The capital stock in this model is given by the reproductive herd. They are animals used to produce beef cattle and consist of suckling cows and heifers that have reached the breeding age. A heifer can be used for reproductive purposes only after eighteen months of age. Because of data limitations, however, we assume that heifers can reproduce only after two years of age, and are actually bred at least once when reaching this age. There are no male animals other than male cattle. Bulls are not explicitly considered in the model, since in the beef sector nearly all male calves grow to male cattle.

The production of young animals is assumed to be proportional to the total number of animals kept in the stock of capital, or reproductive herd. This assumption implies that the number of calves born is determined by the choice of the number of cows in the production capital stock. Hence, if C_t is the number of calves born at period t, and K_t is the reproductive herd at the beginning of period t,

$$C_t = FC_t + MC_t = \lambda K_t \text{ for } \lambda = \lambda_F + \lambda_M < 1 \quad (1)$$

where $FC_t = \lambda_F K_t$ and $MC_t = \lambda_M K_t$ represent females and males calves, respectively.

Assume that there is no calf mortality. The simplification does not change the final results, since the mortality rate is very small and can be neglected in the maximisation of the profit function.

The following constraints summarise the stock-flow relations implied by above assumptions on cattle inventory management. The first constraint describes the evolution of the capital stock. Cows may be kept in the reproductive herd or sold for slaughter. The variation of the actual stock of suckling cows derives from the addition of newly bred heifers δ_{t-1} (gross investment) and from the sale of cows for slaughter VK_{t-1} (disinvestment).

$$K_t = K_{t-1} - VK_{t-1} + \delta_{t-1} \quad (2)$$

The second equation depicts the evolution of the stock of heifers H_t. In each period, the initial stock of heifers and the age distribution of this stock are given from the producer's point of view. Hence, the optimal decision about heifers concerns sale of heifers for slaughter, or selection of heifers for the stock of capital (reproductive herd) and breeding heifers. Breeding increases the stock of cows, since once bred, heifers are cows by definition. Thus, the variation of the actual stock of heifers derives from the addition of newly female calves FC_{t-1}, which have reached the age of twelve months, from the selection of heifers to reproductive purpose δ_{t-1}, and from the sale of heifers for slaughter VH_{t-1}.

$$H_t - H_{t-1} = FC_{t-1} - \delta_{t-1} + VH_{t-1} \quad (3)$$

Similar decisions must be taken with respect to the stock of male animals. However, the decision concerning male cattle clearly does not affect future production of calves.

For male cattle, the cattleman has only two possibilities: sale for slaughter or placement on feed to be sold in the future. Thus, the variation of the actual stock of old male cattle derives from the addition in the stock of male calves η_{t-1}, which have reached the age of twelve months, and from the sale of some of them for slaughter VB_{t-1}.

$$B_t - B_{t-1} = \eta_{t-1} - VB_{t-1} \quad (4)$$

The cattleman can sale male calf now for slaughter or it can enter the male cattle herd. Thus, the allocation of the production of male calves (MC_t) derives from the selection of young male cattle for the replacement of the male cattle herd η_t, and from the sale of some of them for slaughter VMC_t.

$$MC_t = \eta_t + VMC_t \qquad (5)$$

2.2. Modelling representative cattleman behaviour

The cattleman is assumed to maximise profits, not only for this period, but over his entire production horizon. Thus, the producer tries to maximise the expected net present value of his enterprise.

First, a profit function is constructed using years as the unit observation period. This profit function is quadratic in its arguments, a fact that guarantees a unique maximum and that satisfies the condition for the existence of certainty equivalents. The function is maximised by dynamic programming methods to obtain the relevant behavioural relations, which determine the econometric specification.

The cattleman's revenue comes from selling animals for slaughter, at any point in time, the premiums granted according to the number of animals[1], while his costs consists of various production and investment costs (maintenance and ageing costs of the cattle stock kept on farm, cost of breeding/producing calves, feeding costs). Assume that the cattleman maximises his profits not only for this period, but for the whole period for which he is in business. Assume further that we know that the cattleman will be in business *T* periods and then retire. In each period, he must make decisions based on actual facts and on facts that he does not yet know for the future periods.

The features of cattle herd management described above translate into the different choice options for each decision variable. Male are animals that, from the decision-making point of view, can either be sold now or in the future. Heifers can also be sold now, or can be bred and thereby be transformed into cows (added to the capital stock), and in turn used to produce new calves. The reproductive capacity of heifers makes them different, and this difference is expressed in the profit function.

Keeping an animal one more period entails a cost and yields the benefit of being able to sell it in the future. If the cattleman acts rationally, he will decide how many cattle to keep in such a way as to equate marginal expected cost and marginal expected benefit, both discounted to the present period. Given constant unit costs, the function to be maximised by the cattleman may be approximated by the following quadratic expression:

[1] See the annex 1 for more details on the premiums granded under the Common Agricultural Policy.

$$
\begin{aligned}
&\pi(VK_t, VH_t, \delta_t, VMC_t, VB_t, \eta_t / K_t, H_t, B_t, t) \\
&= Max(p_{Kt}VK_t + p_{Ht}VH_t + p_{Mt}VMC_t + p_{Bt}VB_t \\
&+ s_{Kt}K_t + s_{Mt}\eta_t + s_{Bt}\eta_{t-1} \\
&-\frac{1}{2}b_1(K_t - VK_t + \delta_t)^2 - \frac{1}{2}b_2(K_t - VK_t)^2 \\
&-\frac{1}{2}b_3(C_t)^2 \\
&-\frac{1}{2}b_4(H_t - VH_t - \delta_t + FC_t)^2 - \frac{1}{2}b_5(H_t - VH_t - \delta_t)^2 \\
&-\frac{1}{2}b_6(B_t - VB_t + \eta_t)^2 - \frac{1}{2}b_7(B_t - VB_t)^2 \\
&+ rE_t\{\pi(VK_{t+1}, VH_{t+1}, \delta_{t+1}, VMC_{t+1}, VB_{t+1}, \eta_{t+1} / K_{t+1}, H_{t+1}, B_{t+1}, t+1)\})
\end{aligned}
\tag{6}
$$

subject to the constraints (1) to (5).

Where the subscript t refers to the current period, and where $\pi(VK_t, VH_t, \delta_t, VMC_t, VB_t, \eta_t / K_t, H_t, B_t, t)$ is the expected present value of profits. The slaughter prices are p_{Kt} for suckling cows, p_{Ht} for heifers, p_{Mt} for male calves, p_{Bt} for male cattle and the headage premiums are respectively for the suckler cows s_{Kt}, and for the male cattle s_{Mt}, and s_{Bt}.

The terms of π may be interpreted as follows:

- $p_{Kt}VK_t + p_{Ht}VH_t + p_{Mt}VMC_t + p_{Bt}VB_t$ is the total revenue from selling various cattle categories: suckler cows, heifers, male calves, male cattle.

- $s_{Kt}K_t + s_{Mt}\eta_t + s_{Bt}\eta_{t-1}$ is the revenue from premiums. The former premium is granted per cows each year while the latter is granted only twice in the male cattle life. In our model, we assume that a male calf which enter in the cattle herd is grown until the age of two years and that the special beef premium is obtained when a male enters in the cattle herd at the age of twelve month and when he reaches the age of two years, i.e., after one year in the cattle herd[2].

- $-\frac{1}{2}b_1(K_t - VK_t + \delta_t)^2$ is the maintenance cost of the capital stock.

- $-\frac{1}{2}b_4(H_t - VH_t - \delta_t + FC_t)^2$ and $-\frac{1}{2}b_6(B_t - VB_t + \eta_t)^2$ is the feeding cost of respectively, heifers and male cattle. Feeding costs for heifers are assumed to differ from those for male cattle for the following reasons: first, if heifers are kept in part for possible future breeding, there is no need to feed them as much as male cattle; second, the capacity of heifers for transforming feed into weight is less than the capacity of male cattle.

- $-\frac{1}{2}b_3(C_t)^2$ is the production and maintenance cost of calves.

- $-\frac{1}{2}b_2(K_t - VK_t)^2$, $-\frac{1}{2}b_5(H_t - VH_t - \delta_t)^2$ and $-\frac{1}{2}b_7(B_t - VB_t)^2$ is the cost of holding respectively the capital stock , the heifers and the male cattle due to ageing. The ageing costs are also assumed to be different for cows, heifers, and male cattle. It is the additional cost involved in keeping the animal one more period, resulting from the need for more feed and the higher

[2] In fact, during the studying period, the special premium was obtained between 10 and 22 months and after 23 months.

probability of death, etc., as the animal becomes older. The principal element of the aging cost, however, is the loss in value at sale. Animals sold for slaughter are classified by weight, sex, and age. Older animals are generally worth less, ceteris paribus. The productivity and the expected benefits and costs differ according to age.

- r is the one period discount rate,
- E is the expectation operator,
- and $\pi(VK_{t+1}, VH_{t+1}, \delta_{t+1}, VMC_{t+1}, VB_{t+1}, \eta_{t+1} / K_{t+1}, H_{t+1}, B_{t+1}, t+1)$ the profit function for the next period $t+1$.

The main notations used in the framework are summarised in the table 1.

(Insert Table 1)

3. Empirical Implementation: the maximising solution

The method used is dynamic programming, which is a recursive maximisation procedure starting from the last period T, i.e., the period after which the cattleman will retire. In the usual fashion, having obtained the solution for this period, we then solve for the next to last period; and so on, as many times as necessary for determination of the general solution until period t, for any t (Howard, 1966, 317-320).

The model represented by equations (2) and (3) is equivalent to maximising

$$\begin{aligned}&\pi(VK_t, VH_t, \delta_t, VMC_t, VB_t, \eta_t / K_t, H_t, B_t, t)\\ &= \sum r^{T-t}[\pi_t - \beta_{1,t}(K_t - K_{t-1} + VK_{t-1} - \delta_{t-1})\\ &\qquad -\beta_{2,t}(H_t - H_{t-1} + VH_{t-1} + \delta_{t-1} - FC_{t-1})\\ &\qquad -\beta_{3,t}(B_t - B_{t-1} + VB_{t-1} - \eta_{t-1})]\end{aligned} \tag{7}$$

where the Lagrange multipliers $\beta_{1,t}$, $\beta_{2,t}$ and $\beta_{3,t}$ are the shadow prices of an animal in stock for cows, heifers and male cattle . Expression (7) is maximised with respect to VK_t, VH_t, δ_t, VMC_t, VB_t and η_t. The first-order conditions with respect to VK_t, VH_t, δ_t, VMC_t, VB_t and η_t are as follows:

$$\frac{\partial \pi}{\partial VK_t} = p_{Kt} + b_1(K_t - VK_t + \delta_t) + b_2(K_t - VK_t) - r\beta_{1,t+1} = 0$$

$$\frac{\partial \pi}{\partial VH_t} = p_{Ht} + b_4(H_t - VH_t - \delta_t + FC_t) + b_5(H_t - VH_t - \delta_t) - r\beta_{2,t+1} = 0$$

$$\frac{\partial \pi}{\partial VB_t} = p_{Bt} + b_6(B_t - VB_t + \eta_t) + b_7(B_t - VB_t) - r\beta_{3,t+1} = 0$$

$$\frac{\partial \pi}{\partial \delta_t} = -b_1(K_t - VK_t + \delta_t) + b_4(H_t - VH_t - \delta_t + FC_t) + b_5(H_t - VH_t - \delta_t) + r\beta_{1,t+1} - r\beta_{2,t+1} = 0$$

$$\frac{\partial \pi}{\partial \eta_t} = -p_{Mt} + s_{Mt} + rs_{Bt+1} - b_6(B_t - VB_t + \eta_t) + r\beta_{3,t+1} = 0$$

Solving for VK_t, VH_t, VMC_t, VB_t, δ_t and η_t we find:

$$VK_t = K_t + \frac{1}{b_2} p_{Kt} - \frac{1}{b_2} p_{Ht} \tag{8}$$

$$VH_t = H_t - \delta_t + \frac{1}{b_4+b_5} p_{Ht} - \frac{r}{b_4+b_5}\beta_{2,t+1} + \frac{b_4}{b_4+b_5} FC_t \tag{9}$$

$$VB_t = B_t + \frac{1}{b_7} p_{Bt} - \frac{1}{b_7} p_{Mt} + \frac{1}{b_7} s_{Mt} + \frac{1}{b_7} s_{Bt+1} \tag{10}$$

$$\delta_t = \frac{1}{b_2} p_{Kt} - (\frac{1}{b_1} + \frac{1}{b_2}) p_{Ht} + \frac{r}{b_1}\beta_{1,t+1} \tag{11}$$

$$\eta_t = \frac{1}{b_7} p_{Bt} - (\frac{1}{b_6} + \frac{1}{b_7}) p_{Mt} + \frac{r}{b_6}\beta_{3,t+1} + (\frac{1}{b_6} + \frac{1}{b_7}) s_{Mt} + (\frac{1}{b_6} + \frac{1}{b_7}) s_{Bt+1} \tag{12}$$

$$VMC_t = MC_t - \frac{1}{b_7} p_{Bt} - (\frac{1}{b_6} + \frac{1}{b_7}) p_{Mt} + \frac{r}{b_6}\beta_{3,t+1} + (\frac{1}{b_6} + \frac{1}{b_7}) s_{Mt} + (\frac{1}{b_6} + \frac{1}{b_7}) s_{Bt+1} \tag{13}$$

Substituting these equations into the three constraints controlling the evolution of the stock variables, K_t, H_t, and B_t are given by:

$$K_t = -\frac{1}{b_1} p_{Ht-1} + \frac{r}{b_1}\beta_{1,t} \tag{14}$$

$$H_t = -\frac{1}{b_4+b_5} p_{Ht-1} + \frac{r}{b_4+b_5}\beta_{2,t} + \frac{b_5}{b_4+b_5} FC_{t-1} \tag{15}$$

$$B_t = -\frac{1}{b_6} p_{Mt-1} + \frac{r}{b_6}\beta_{3,t} + \frac{1}{b_6} s_{Mt-1} + \frac{r}{b_6} s_{Bt} \tag{16}$$

The first-order conditions for the stock variables K_t, H_t and B_t are:

$$\frac{\partial\pi}{\partial K_t} = p_{Mt}\lambda_M + s_{Kt} - b_1(K_t - VK_t + \delta_t) - b_2(K_t - VK_t) - b_3\lambda^2 K_t - b_4\lambda_F(H_t - VH_t - \delta_t + \lambda_F K_t)$$
$$-\beta_{1,t} + r\beta_{1,t+1} \quad + r\lambda_F\beta_{2,t+1} = 0$$

since $C_t = \lambda K_t$, $MC_t = \lambda_M K_t = VMC_t - \eta_t$ and $FC_t = \lambda_F K_t$

$$\frac{\partial\pi}{\partial H_t} = -b_4(H_t - VH_t - \delta_t + FC_t) - b_5(H_t - VH_t - \delta_t) - \beta_{2,t} + r\beta_{2,t+1} = 0$$

$$\frac{\partial\pi}{\partial B_t} = -b_6(B_t - VB_t + \eta_t) - b_7(B_t - VB_t) - \beta_{3,t} + r\beta_{3,t+1} = 0$$

Thus, the shadow prices are given by:

$$\beta_{1,t} = \gamma_1(s_{Kt} + p_{Kt}) + \gamma_2 p_{Ht-1} + \gamma_3 p_{Ht} + \gamma_4 p_{Ht+1} + \gamma_5 p_{Mt}$$

$$\beta_{2,t} = p_{Ht}$$

$$\beta_{3,t} = p_{Bt}$$

where $\gamma_0 = b_3\lambda^2 + \frac{b_4 b_5}{b_4+b_5}\lambda_F^2$, $\gamma = 1 + \frac{r}{b_1}\gamma_0$, $\gamma_1 = \frac{1}{\gamma}$, $\gamma_2 = \frac{\gamma_0}{\gamma\, b_1}$, $\gamma_3 = \frac{b_4\lambda_F}{\gamma(b_4+b_5)}$, $\gamma_4 = \frac{rb_5\lambda_F}{\gamma(b_4+b_5)}$ and $\gamma_5 = \frac{\lambda_M}{\gamma}$

At the optimum, the Lagrange multipliers associated with the stock-flow constraints for heifers and male cattle are equal to the corresponding slaughter prices. The expression of the shadow price for cows is more complicated, owing to the reproductive capacity of these animals: the shadow price of cows is a linear combination of their slaughter value p_{Kt} and their capital value in production, which in turn depends on expected future prices of heifers.

The first conditions derives above can be solved for each endogenous variable in terms of past, current and future price levels, and lagged values of the capital stock. Following Nerlove and Fornari (1998), we obtain the *Expectationally Conditional Reduced Form* (ECRF) of the dynamic maximisation model, that expresses endogenous variables in terms of exogenous and predetermined ones, conditional on expectations of future levels of exogenous variables.

Omitting the expectations operator for simplicity, the ECRF for the optimal decision variables (VK_t, VH_t, δ_t, VMC_t, VB_t, η_t) and for the stock variables (K_t, H_t, B_t) are the equations:

$$K_t = \frac{r\gamma_1}{b_1}(p_{Kt}+s_{Kt}) + (-\frac{1}{b_1}+\frac{r\gamma_2}{b_1})p_{Ht-1} + \frac{r\gamma_3}{b_1}p_{Ht} + \frac{r\gamma_4}{b_1}p_{Ht+1} + \frac{r\gamma_5}{b_1}p_{Mt} \tag{17}$$

$$\begin{aligned} VK_t = {} & \frac{r\gamma_1}{b_1}s_{Kt} + (\frac{r\gamma_1}{b_1}+\frac{1}{b_2})p_{Kt} + (\frac{r\gamma_2}{b_1}-\frac{1}{b_1})p_{Ht-1} + (\frac{r\gamma_3}{b_1}-\frac{1}{b_2})p_{Ht} + \frac{r\gamma_4}{b_1}p_{Ht+1} \\ & + \frac{r\gamma_5}{b_1}p_{Mt} \end{aligned} \tag{18}$$

$$\begin{aligned} H_t = {} & \frac{b_5}{b_1(b_4+b_5)}(r\gamma_2-1)p_{Ht-2} + \frac{1}{b_4+b_5}(\frac{b_5 r\lambda_F\gamma_3}{b_1}-1)p_{Ht-1} + \frac{r}{b_4+b_5}(1+\frac{b_5 r\lambda_F\gamma_4}{b_1})p_{Ht} \\ & + \frac{b_5\lambda_F r\gamma_1}{b_1(b_4+b_5)}(p_{Kt-1}+s_{Kt-1}) + \frac{b_5\lambda_F r\gamma_5}{b_1(b_4+b_5)}p_{Mt-1} \end{aligned} \tag{19}$$

$$\begin{aligned} VH_t = {} & \frac{b_5\lambda_F}{b_1(b_4+b_5)}(r\gamma_2-1)p_{Ht-2} + \frac{1}{b_4+b_5}[\frac{b_5\lambda_F r\gamma_3}{b_1} - 1 + \frac{b_4\lambda_F}{b_1}(r\gamma_2-1)]p_{Ht-1} \\ & + [\frac{r}{b_4+b_5}(1+\frac{b_5\lambda_F r\gamma_4}{b_1}) + \frac{1}{b_1} + \frac{1}{b_2} - \frac{r\gamma_2}{b_1} + \frac{1}{b_4+b_5}(1+\frac{b_4\lambda_F r\gamma_4}{b_1})]p_{Ht} \\ & + (\frac{b_4\lambda_F r\gamma_4}{b_1(b_4+b_5)} - \frac{r}{b_4+b_5} - \frac{r\gamma_3}{b_1})p_{Ht+1} - \frac{r\gamma_4}{b_1}p_{Ht+2} + \frac{rb_5\lambda_F\gamma_1}{b_1(b_4+b_5)}(p_{Kt-1}+s_{Kt-1}) \\ & + [-\frac{1}{b_2} + \frac{b_4\lambda_F r\gamma_1}{b_1(b_4+b_5)}]p_{Kt} - \frac{b_4\lambda_F r\gamma_1}{b_1(b_4+b_5)}s_{Kt} - \frac{r\gamma_1}{b_1}(p_{Kt+1}+s_{Kt+1}) \\ & - \frac{rb_5\lambda_F\gamma_5}{b_1(b_4+b_5)}p_{Mt-1} + \frac{rb_4\lambda_F\gamma_5}{b_1(b_4+b_5)}p_{Mt} - \frac{r\gamma_5}{b_1}p_{Mt+1} \end{aligned} \tag{20}$$

$$\delta_t = \frac{1}{b_2}p_{Kt} + \frac{r\gamma_1}{b_1}(p_{Kt+1}+s_{Kt+1}) + \left[-(\frac{1}{b_1}+\frac{1}{b_2}) + \frac{r\gamma_2}{b_1}\right]p_{Ht} + \frac{r\gamma_3}{b_1}p_{Ht+1} + \frac{r\gamma_4}{b_1}p_{Ht+2} + \frac{r\gamma_5}{b_1}p_{Mt+1} \tag{21}$$

$$B_t = -\frac{1}{b_6}p_{Mt-1} + \frac{r}{b_6}p_{Bt} + \frac{1}{b_6}(s_{Mt-1}+rs_{Bt}) \tag{22}$$

$$VB_t = (\frac{r}{b_6}+\frac{1}{b_7})p_{Bt} - \frac{1}{b_6}p_{Mt-1} - \frac{1}{b_7}p_{Mt} + \frac{1}{b_6}s_{Mt-1} + \frac{1}{b_7}s_{Mt} + \frac{r}{b_6}s_{Bt} + \frac{r}{b_7}s_{Bt+1} \tag{23}$$

$$\eta_t = \frac{1}{b_7}p_{Bt} - (\frac{1}{b_6}+\frac{1}{b_7})p_{Mt} + \frac{r}{b_6}p_{Bt+1} + (\frac{1}{b_6}+\frac{1}{b_7})(s_{Mt}+rs_{Bt+1}) \tag{24}$$

$$\begin{aligned} VMC_t = {} & (\frac{r\lambda_M\gamma_5}{b_1}+\frac{1}{b_6}+\frac{1}{b_7})p_{Mt} - \frac{1}{b_7}p_{Bt} - \frac{r}{b_6}p_{Bt+1} - (\frac{1}{b_6}+\frac{1}{b_7})(s_{Mt}+rs_{Bt+1}) \\ & + \frac{r\lambda_M\gamma_1}{b_1}(p_{Kt}+s_{Kt}) + \frac{\lambda_M}{b_1}(r\gamma_2-1)p_{Ht-1} + \frac{r\lambda_M\gamma_3}{b_1}p_{Ht} + \frac{r\lambda_M\gamma_4}{b_1}p_{Ht+1} \end{aligned} \tag{25}$$

The expected effects of the exogenous variables (observed and anticipated prices, levels of current and anticipated premiums) on the endogenous variables (numbers of animals and levels of slaughtering) derived from the model are summarised in Tables 2.

(Insert Table 2a)

(Insert Table 2b)

(Insert Table 2c)

The only unambiguous effect concerns the impact of headage premiums. The sukler cow premiums should have always a positive effect on the sales and the number of animals. The effect of anticipated prices cannot be predicted in general, while the impact of observed prices is in general indeterminate, depending on the value of the estimated shadow costs.

4. Econometric analysis

In the following section we describe the econometric estimation techniques, the data used in the econometric analysis, and lastly discuss the results from the estimation.

Price and premium expectation formulation

For each anticipated price, we use the following formulation

$$p^*_{t+1} = \alpha_1 p_{t-2} + \alpha_2 p_{t-1} + \alpha_3 p_t$$

where p^*_{t+1} is the anticipated price that each producer makes in t for the following time period $t+1$, p_{t-i} is the current price in $t-i$,and $\alpha_1, \alpha_2, \alpha_3$ are the coefficients to be estimated.

For each anticipated premium, we use naive expectations since each producer knows the value of premiums for each year:

$$s^*_{t+1} = s_t$$

The data

The data for France are drawn from the national Farm Business Survey for the 1995-1997 years. These is annual national survey collected by agencies of the government. The sample of farms are chosen so as to be representative of national agriculture in the country. In general, each survey farm remains in the survey for 5 or 6 years. Hence, a balanced panel of 343 farms can be constructed for the period.

The results for suckler cows

Equations (17) to (25) have been estimated by OLS. Although the ECRF expressions determine the optimal supply functions and gross investment behaviour of the producer, in terms of his anticipations of future price levels and predetermined variables, their evident complexity and the presence of many cross- and within equations restrictions present formidable obstacles to empirical investigation. The large number of leads and lags in the price and stock variables, the appearance of the same parameters in different equations, the large number and non-linear nature of cross-equation restrictions on parameters, create difficulties in direct estimation. Hence, in a first step we estimate the unrestricted model.

(insert Table 3)

For the number of the cow, all the coefficients in the regression which are statically significant have the predicted sign. We can note the negative effect of the price of heifers showing the substitution between cows and heifers. The suckler cow premium has an important positive effect. For the equation explaining the sales of cows as expected from the model, the price of the cows and the suckler cow premium have a positive and significant effect.

The last table provides a comparison between the effect of a decrease in the current price level and an increase in the current premium for the suckler cows.

Tableau 4. Elasticities of suckler cow variables relative to slaughter price and premium.

Variables	Slaughter price for cows	Suckler cow premium
Number of cows	-0,00026	0,017
Sales of cows	0,313	0,018
Heifers added to the herd	0,029	0,016

Elasticities are evaluated at the means of the sample. For that point the number of cows is 56.53, the cow price is 6182 F, the suckler cow premium is 1260 F the heifers added to the herd is equal to 11.20 and the average number of slaughtered cows is 10,75.

For each variable, there exists a positive effect of the slaughter price which is larger than the effect of premium.

5. Concluding remarks

This paper has provided a dynamic optimisation model to describe the behaviour of a representative cattleman maximising his expected profits over an infinite time horizon. It allows us to derive a reduced form which defines each endogenous variables (sales of different animal categories and investment in the herd) by current, past and future exogenous variables as slaughter prices or headage premiums. The model is estimated on a balanced panel data set of 353 farms for the French cattle sector for the period 1995-1997.

Results from the estimation show a positive effect of the premium which is larger than the effect of slaughter price concerning the choices of the number of cows maintained in the herd and the sales of cows during the current period.

The disaggregation by animal categories is helpful in assessing supply response to changes in market conditions or in agricultural policy. This work can be extended in two directions. Firstly, the various equations of the reduced form should be estimated simultaneously. The second extension is the introduction of the land in the model to compare the effects of alternative payments on beef supply (payments based on land or payments based on animals).

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Table 1. Notations and definitions

Number of animals (stock variables)	
K_t	Reproductive herd at the beginning of the period t
H_t	Stock of heifers at the beginning of the period t
B_t	Male cattle at the beginning of the period
C_t	Total calves born at period t
FC_t	Females calves born at period t
MC_t	Males calves born at period t
Slaughter variables (disinvestment)	
VK_t	Sales of cows for slaughter
VH_t	ales Heifers for slaughter
VB_t	Sales of male cattle for slaughter
VMC_t	Males calves sales for slaughter
Investment	
η_t	Selection of young male cattle for replacement of the male
δ_t	Heifers added to the reproductive herd
Slaughtering prices	
p_{Kt}	Slaughter cows price
p_{Ht}	Slaughter heifers price
p_{Mt}	Slaughter males calves price
p_{Bt}	Slaughter males calves price
Premiums	
s_{Kt}	Suckler cow premium
s_{Mt}	First special beef premium
s_{Bt}	Second special beef premium

Table 2a. Expected effects of observed past and current prices

Slaughter prices	Calves		Heifers		Cows		Male cattle
	p_{Mt-1}	p_{Mt}	p_{Ht-1}	p_{Ht}	p_{Kt-1}	p_{Kt}	p_{Bt}
Reproductive herd K_t	ni	-	?	?	ni	+	ni
Stock of heifers H_t	ni	-	?	+	ni	+	ni
Male cattle B_t	-	ni	ni	ni	ni	+	+
Cows sales VK_t	ni	-	?	?	ni	+	ni
Sales of heifers VH_t	+	+	?	?	+	?	ni
Sales of male cattle VB_t	-	-	ni	ni	ni	ni	+
Sales of males calves VMC_t	ni	+	?	+	ni	+	-
Selection of young male cattle η_t	ni	-	ni	ni	ni	ni	+
Heifers added to the reproductive herd δ_t	ni	ni	ni	?	ni	+	ni

ni means that the variable is not included in the specification. The lagged beef price does not appear in any equation.

Table 2b. Expected effects of the anticipated variables

Slaughter prices	Calves	Heifers		Cows	Male cattle	Premiums	
	p_{Mt+1}	p_{Ht+1}	p_{Ht+2}	p_{Kt+1}	p_{Bt+1}	s_{Kt+1}	s_{Bt+1}
Reproductive herd K_t	ni	+	ni	ni	ni	ni	ni
Sales of cows VK_t	ni	+	ni	ni	ni		
Sales of heifers VH_t	-	?	-	-	ni	-	ni
Sales of male cattle VB_t	ni	ni	ni	ni	ni	ni	+
Sales of males calves VMC_t	ni	+	ni	ni	-	ni	-
Selection of young male cattle η_t	ni	ni	ni	ni	+	ni	+
Heifers added to the reproductive herd δ_t	+	+	+	+	ni	+	ni

For the stock of heifers (H_t) and the number of male cattle (B_t), there are no anticipated variables in the equations.

Table 2c. Expected effects of the premiums

Premiums	Suckler cows		Male cattle (first)		Male cattle (second)
	s_{Kt-1}	s_{Kt}	s_{Mt-1}	s_{Mt}	s_{Bt}
Reproductive herd K_t	ni	+	ni	ni	ni
Stock of heifers H_t	+	ni	ni	ni	ni
Male cattle B_t	ni	ni	+	ni	+
Sales of cows VK_t	ni	+	ni	ni	ni
Sales of heifers VH_t	+	+	ni	ni	ni
Sales of male cattle VB_t	ni	ni	+	+	+
Sales of males calves VMC_t	+	ni	ni	-	ni
Selection of young male cattle η_t	ni	ni	ni	+	ni

For the heifers added to the reproductive herd (δ_t), there are only an effects of the expected Suckler cow premium.

Table 3. Estimates for the number of cows, the sales of cow sand the number of heifers added to the herd

	Dependent variables		
	Number of cows K_t	Cows sales VK_t	Heifers added to the herd
Intercept	5.141 (2.54)	-3.518 (1.63)	-4.037 (-2.11)
p_{Kt}	$0.238*10^{-3}$ (-0.10)	$0.550*10^{-3}$ (2.55)	$0.543*10^{-4}$ (0.19)
p_{Kt-1}	—	—	$0.594*10^{-3}$ (2.06)
p_{Kt-2}	—	—	$0.221*10^{-3}$ (0.81)
p_{Ht}	$-0.346*10^{-4}$ (-1.86)	$-0.137*10^{-4}$ (-0.09)	$-0.103*10^{-3}$ (0.66)
p_{Ht-1}	$-0.176*10^{-4}$ (-0.09)	$0.715*10^{-4}$ (0.47)	$0.112*10^{-3}$ (0.71)
p_{Ht-2}	$0.224*10^{-4}$ (-1.86)	$0.307*10^{-3}$ (1.99)	$0.186*10^{-2}$ (1.18)
p_{Mt}	$-0.647*10^{-3}$ (-2.06)	$-0.442*10^{-3}$ (-1.75)	$0.181*10^{-4}$ (0.05)
p_{Mt-1}	—	—	$0.186*10^{-2}$ (1.18)
p_{Mt-2}	—	—	$-0.750*10^{-4}$ (0.25)
s_{Kt}	$0.760*10^{-3}$ (44.87)	$0.152*10^{-3}$ (11.16)	$0.145*10^{-3}$ (10.23)
R^2	0.87	0.36	0.34
DW	1.83	1.89	1.96

The t ratios are reported in brackets under the coefficients.

Annex 1 Definition and Construction of Variables

The model used requires a desegregation of the livestock into four categories of animals: calves, heifers, cows and the number of male cattle. In the data set, we have available information for each category of animals on the stock of animals on the farm at the beginning of the period.

Furthermore we have information on levels slaughtering for each category of animals measured in value and in number of animals. Hence we can calculate the slaughter price.

For the premiums, we have available information on the total of amount of premiums for each category of animals. Under the Common Agricultural Policy, the premiums are granted accordingly to the number of animals (each year for suckler cows, once or twice in the life for male bovine animals), but they are submitted to a maximum of heads on each holding (for male premium) and a maximum stocking density, that is, live units per hectare (for both male and suckler premiums). From a technical point of view, a special beef premium is granted twice in the cattle life within ceilings set at regional level on up to 90 male animals per age bracket, per calendar year and per holding. The first special premium is obtained when male cattle age is between 10 and 22 months and the second one after 23 months. For holding suckler cows, a premium is granted each year. This entitlement is restricted by an individual ceiling set by reference to a base year (1992 in France). Eligibility of animals for the special premium or for the suckler cow premium is limited by the application of a density factor of (for 1997) 2.0 livestock units (LU) per hectare of forage for the animals which a premium application has been made. An additional extensification premium is payable per head of eligible suckler cows and male cattle if the stocking density is less than 1.4 or 1.0 LU/ha.

By using the total amount of premiums in the estimations, we take into account the ceilings