Agricultural Policy in a Vertical Structure of Production with an Application to the Milk Industry

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Abstract: This paper analyzes the effects of policy instruments used in the dairy sector. The analysis considers the supply of milk, the processing step characterized by joint production and the final demand for processed goods. A short term partial equilibrium model is defined. We use it to determine the effects of different policy scenarios on price, production, consumption and exports for the different products. Because the GATT agreements imply a decrease in the volume of subsidized exports, we particularly analyze the impact of policy instruments on the exports of different milk products.

Keywords: public intervention, dairy industry, multiproduction, vertical structure, joint production.

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In most OECD countries, milk production benefits from large support. The GATT agreements reached in Marrakech in 1995 have not yet led to strong changes in dairy policies, which remain very protective. In the European Union (EU) for example, these agreements mainly consist of lowering subsidies for dairy product exports. But, deeper changes in dairy policy will certainly occur. For example, Danish and French producers, have proposed a two price plan system (ATLA, 1997). Moreover, the European Commission has recently proposed to lower the intervention prices of butter and skim milk powder by 15%, to increase the level of the milk quota by 2%and to give direct payments in order to compensate producers.

However, research on dairy policies have mainly been concerned with the impact of the quota system (Burrell, 1989; OECD, 1990). Moreover, even when a broader range of policies are investigated, the studies often only consider an aggregate final product (OECD, 1991). They do not consider the set of final products. This is a strong limitation of these studies because dairy policy is based on intervention in the markets of some specific final products (for example, intervention prices of butter and milk powder, export subsidies for different products, etc.). These interventions influence the production decision of the processing firms. Thus, as shown by Oskam (1989), we have to take into account the main characteristics of the processing stage.

Analysis of the efficiency of policy instruments in supporting farm revenues is well documented in the literature (Gardner, 1983; Alston and Hurd, 1990; Moschini and Sckokai, 1994). These

studies are developed in a partial equilibrium framework and often assume mono-production.[1] None of these works has considered joint production which is a major characteristic of the milk processing industry. Gardner (1987) proposes a general method for analyzing the comparative static of policy intervention. In this paper, we will use this methodology in the context of vertically related markets with joint production.

This paper is organized as follows: section 1 presents the main characteristics of public regulation in the dairy sector. Section 2 presents the equilibrium model. In section 3, we analyze the effects of changes in the level of policy instruments. Section 4 gives some results applied to the European sector and section 5 presents our conclusions.

1. Public regulation of the dairy sector in the EU

The basis of the common organization of the markets for milk and dairy products was defined in 1968 by regulation 804/68. Quotas on milk production were introduced in 1984, but the basic mechanism of intervention has remained unchanged since 1968. A target price for milk is fixed each year. An intervention price for butter and for skim milk powder are also fixed at the same time. Throughout the year, under defined conditions, the intervention agency has to buy butter and skim milk powder at the intervention prices. In order to make these products competitive with their substitutes, butter and skim milk are subsidized in the EU (the use of butter in the food industry, the use of skim milk as feedstuff, the processing of skim milk into casein). Trade with third countries is also regulated: imports are subject to duties and exports benefit from export refunds.

[1] Guyomard and Mahé (1995) analyze the 1992 agricultural policy reform in a context of multi-production.

In accordance with the Agreement on Agriculture concluded during the Uruguay Round of the GATT trade negotiations, export refunds on agricultural products are issued each year up to a maximum quantity and a maximum value. These maximum levels for quantity and value of exports are reduced every year over a six-year period. By the year 2000, the final levels of the decreases are to reach 21% and 36%, respectively. Compared with the actual exports in 1995, these constraints mainly concern cheese and « other milk products » but also skim milk powder (see Table 1).

Table 1: Commitment on subsidized exports (GATT agreement) and actual levels in 1995 in the European Union.

	Reference	Commitment 1995	Commitment 2000	Actual level 1995
Subsidized quantity (1000 t)				
Skim milk powder	344.9	335	272.5	402*
Butter and butter oil	505.5	487.8	399.3	227
Cheese	406.7	426.5	321.3	524
Other dairy products	1212.8	1185.4	958.1	1324
Budgetary Expenditures (M ecus)				
Skim milk powder	430.9	406.2	275.8	199
Butter and butter oil	1481	1392.1	947.8	477
Cheese	533.9	594.1	341.7	583
Other dairy products	1212.8	1185.4	958.1	1324

* Including a 100,000 t decrease in stocks Source: EC, 1997

The level of support to the dairy sector remains high. For example, in the EU, budgetary costs were greater than 5 billion ecus in 1993, which is equivalent to 15% of expenditure levels. Export refunds represented 44%, subsidies to industrial uses of butter and skim milk powder

were respectively 13% and 16% of budgetary costs. OECD (1995) evaluates the producer subsidy equivalent (PSE) to 21 billion ecus in the EU, that is equal to 63% of the value of production. On average in OECD countries, PSE in milk production are as high as 62% of the value of production. Then, in most industrialized countries except New Zealand, milk production remains a highly protected sector.

2 - A dairy product equilibrium model

We analyze the effects of policy intervention scenarios on the equilibrium of dairy markets. The dairy industry is represented as a vertical structure which includes the supply of a raw agricultural product, a transformation stage and the demand for processed commodities. The processing of the agricultural output into commodities is divided into two steps. In the first step, the agricultural product (milk) is used to produce two intermediate goods in a strict joint production framework. In the second step, these two intermediate products are used and recombined by the processing industry to produce the commodities. [2]

The conceptual model includes three commodities. The first commodity is produced using only the first intermediate product, the second using only the second intermediate product while the third commodity is produced using a combination of both intermediate products.

Each commodity faces an aggregate demand composed of a domestic demand and a world demand. The foreign export demand explicitly shows the export subsidy rate:

$$(1) \qquad Y_i^D = D_i^i\left(P_i, Z_{i1}\right) + D_i^x\left(P_i - R_i, Z_{i2}\right),\ i \in \{b, p, c\},$$

[2] We consider that the agricultural product has two main components, fat and proteins. These two components can be used to produce two intermediate products for which the ratio of fat to proteins is different from that of the raw product. For one of the two intermediate products, the ratio of fat to proteins is greater than the ratio for milk (we call it cream) and for the other one, the ratio will be lower (we call it skim milk). Combining these

where Y_i^D is the quantity of commodity *i* demanded by consumers, D_i^i and D_i^x are the domestic and world demands for commodity *i*, P_i is the price of *i*, R_i is the unit export refunds on commodity *i* and Z_{i1} and Z_{i2} are exogenous variables influencing demand. Indexes *(b, p, c)* represent respectively butter, skim milk powder and cheese. The demands are decreasing functions of the price.

Milk supply is a function of its price and of an other exogenous variable. It is given by:

(2) $X = g(P_x, Z_x)$,

where X is the total quantity produced, P_x is the price of raw milk and Z_x is an exogenous variable which can influence milk supply. The function *g* is an increasing function of P_x. Milk quota will be introduced in the model by including the equation $X \leq \overline{X}$ where $\overline{X}$ is the level of the production quota.

We assume that the raw agricultural product is then used to produce a fixed proportion of intermediate products. This assumption is justified in a short-term framework in which the composition of milk is supposed to be fixed. Thus,

(3) $Y_j = \gamma_j X$, $j \in \{cr, sm\}$,

where Y_j is the produced quantity of intermediate good *j*, γ_j is the transformation coefficient of milk into intermediate product *j*. The indexes *(cr, sm)* represent respectively cream and skim milk.

The intermediate goods are then used in fixed proportions to produce the three commodities:

(4) $Y_i^S = \gamma_{ji} Y_{ji}$, $i \in \{b, p, c\}$, $j \in \{cr, sm\}$,

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two intermediate products in variable proportions defines a range of commodities for which the ratio of fat to

where Y_i^S is the supplied quantity of commodity *i*, Y_{ji} is the quantity of intermediate good *j* used in the production of the processed good *i*, γ_{ji} is the transformation coefficient of the intermediate good *j* into the commodity *i*. The transformation coefficient of skim milk into butter (γ_{smb}) is equal to zero because only cream is needed to produce butter. Similarly, the transformation coefficient of cream into skim milk powder (γ_{crp}) is equal to zero. Cheese is produced from a combination of the two intermediate products. In the conceptual model, cheese reflects the range of dairy commodities for which the ratio of fat to proteins are between the ratio for butter and for skim milk powder.

At the equilibrium, supply equals demand. We write:

(4') $Y_i^S = Y_i^D = Y_i,\ i \in \{b, p, c\}$.

The total quantities of cream and skim milk are used entirely to produce either cheese, butter or skim milk powder. Thus, we can write the equilibrium equation of intermediate products as follows:

(5) $Y_j = \sum_i Y_{ji},\ j \in \{cr, sm\}$, where $Y_{smb} = Y_{crp} = 0$.

Furthermore, in addition to the dairy intermediate products, the use of other factors of production such as labor and energy are necessary to produce the set of commodities (we denote by *a*, the vector of other inputs). In the short run, we assume that substitution among the factors of production is allowed, but that they can not be substituted for the intermediate products. Under this assumption, the production function of the processed good *i* can be written as: $Y_i = \min(\gamma_{cri} Y_{cri}, \gamma_{smi} Y_{smi}, f(a))$ where *f(a)* is the quantity of final good Y_i

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protein changes in the interval of the ratios defined for the two intermediate products.

potentially produced from the other inputs. If P_a is the price vector of the other inputs *a*, it is easy to check that the dual cost function takes the following form:[3]

$$C\left(Y_i, P_c, P_e, P_A\right) = \sum_j P_j \frac{Y_i}{\gamma_{ji}} + c(Y_i, P_A).$$

The cost function is written as the sum of two terms: the purchasing cost of intermediate products and the purchasing cost of other factors. We make the assumption that the cost of other factors is proportional to the level of production (this means in particular that the price of other factors is fixed). Then the marginal transformation cost (except for the purchase of intermediate products) is constant. Under a perfect competition assumption, the first order conditions of the transformers' program imply that:

$$(6) \qquad P_i = \sum_j \frac{1}{\gamma_{ji}} P_j + C_i, \; i \in \{b, p, c\},$$

where C_i is the marginal cost of processing cream and skim milk into the commodity *i*. C_i is assumed to be fixed. In the same way , the first order condition of milk transformation into its components is written as:

$$(7) \qquad P_x = \sum_j \gamma_j P_j - C_x,$$

where C_x is the marginal cost of processing milk into cream and skim milk.

In a production quota framework, equation (7) implicitly assumes that the price support on processed products is entirely transferred to milk producers. In this model, the production price of intermediate factors (cream and skim milk) is explicitly written. In other studies, the

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[3] At the optimum, we have the identity $Y_i = \bar{Y}_i$. Moreover, we can demonstrate that if $f(a) \neq \gamma_{ji} Y_{ji}$ then the use of a factor can be reduced without decreasing the production. Therefore, it is not an optimum and we must have the identity $f(a) = \gamma_{ji} Y_{ji}$.

transformation step of milk into cream and skim milk is not explicitly written. They rather determine the implicit value of fat and protein contents of the raw agricultural product (Cox, Chavas and Jesse, 1994).

Endogenous variables of the model include equilibrium prices and quantities and exogenous variables include the supply and demand elasticities and the technological coefficients.

3 - Market equilibrium and public intervention

The commitment undertaken in the GATT agreement implies some adjustments in the European dairy policy. Therefore, the EC has reduced subsidies on cheese exports to some destinations. However, in a general way, we can analyze changes in the intervention price of butter (or skim milk powder), in the level of production quotas, or in the amount of export subsidies on cheese. In order to analyze the effect of a change in one of the variables set by the public regulator on the endogenous variables, we totally differentiate each equation of the model and write the changes in elasticity form.[4] Table 2 gives the effects of the three policy scenarios on price, production, consumption and exports variables.

First, we analyze the impact of an exogenous change in the intervention price of butter in the case of a milk quota. Given the prices, the milk quota is restrictive and the dual price of milk is less than the market price (Barkaoui, Buttault and Guyomard, 1996). Thus, a marginal change in the price of milk has no impact on the supply of milk and, therefore on the supply of intermediate products (cream and skim milk). The decrease in the price of butter implies a decrease in the production of butter and thus in the quantity of cream used to produce butter.

This enhances a larger production of cheese. This leads to a rise in the quantity of skim milk used in the production of cheese and thus to a decrease in the quantity used in the production of skim milk powder, thereby reducing the supply of skim milk powder. Prices of commodities change in the opposite direction to that of the supplied quantities. Therefore, the price of skim milk powder goes up and the price of cheese decreases. The decrease in the price of butter implies a decrease in the price of cream, while the rise in the price of skim milk powder leads to a rise in the price of skim milk. Finally, the price of milk is lowered because the increase in the price of skim milk does not compensate the decrease in the price of cream. The domestic consumption of butter increases and the volume of export decreases as a result of the negative change in the price of butter. Moreover, the export subsidy on butter is reduced in response to the reduction in the domestic price but also to the rise in the world price (due to the decrease in the exports). Following the reduction in the production of butter, the exports of cheese increase and the exports of skim milk powder decrease. Thus, a reduction in price of butter negatively affects GATT constraints as it implies an increase in the exports of cheese (even though the constraint on cheese is already binding).

To satisfy the GATT export constraints, the public regulator can also intervene on the level of the milk quota. An exogenous reduction in the level of quota leads to a decrease in the supply of intermediate products. On the one hand, the decrease in the production of cream lowers the supply of butter and cheese. Therefore, the quantity of skim milk used in the production of cheese is also reduced in favor of the production of skim milk powder. On the other hand, the cut down in the supply of milk implies a decrease in the production of skim milk (and,

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[4] We divide each differential by the required variable and write each equation in percentage form. We then express each partial derivative as an elasticity. The resolution of this system is realized with Mathematica. For

therefore in the quantity of skim milk used to produce skim milk powder). The second effect (reduction in the supply of milk) is greater than the factor reallocation effect, so that the change in the supply of skim milk powder is negative. The decrease in the production of the three commodities leads to a rise in their prices, but also in the prices of the intermediate products and thus in the price of milk. Such a policy induces a decrease in the exports of all the final products.

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further details on the method, see Gardner (1987).

Table 2 : Effects of scenarios on price, production, consumption and exports variables.

	Scenario I	Scenario II	Scenario III
BUTTER			
Production	-	-	+
Domestic consumption	+	-	+
Exports	-	-	+
Price	INT	+	-
Unit export refunds	-	0	0
SKIM MILK POWDER			
Production	-	-	+
Domestic consumption	-	-	+
Exports	-	-	+
Price	+	+	-
Unit export refunds	0	0	0
CHEESE			
Production	+	-	-
Domestic consumption	+	-	+
Exports	+	-	-
Price	-	+	-
Unit export refunds	0	0	INT
MILK			
Production	0	INT	0
Price	-	+	-

Scenario I: Decrease in the intervention price of butter in a milk quota framework.
Scenario II: Decrease in the level of quota.
Scenario III: Decrease in the level of unit refunds on cheese in a milk quota framework.

Finally, we consider a decrease in the unit export subsidy on cheese. The first effect is to reduce the price and the supply of cheese so that the change in the consumption of cheese in the domestic market is positive and the change in the export volume is negative. Then, the decrease in the price of cheese is transmitted to the price of cream and skim milk powder and finally to the price of milk. This reduction in the price of inputs induces a rise in the production of the two other commodities (butter and skim milk powder) and to a decrease in their corresponding prices. A cut down in the unit refunds for cheese makes the constraints on the refunds for the other two processed goods more restrictive.

4 - Policy reform in the European milk sector

We calibrate the formal model using aggregate data on the EC dairy market. The quantitative model distinguishes 7 final products: butter, skim milk powder, whole milk powder, hard and semi-hard cheese, other cheese, liquid milk and other products. Several scenarios of policy reform are evaluated (decrease in the exports refunds, a two price plan, decrease in the level of milk quota, etc.). As the GATT agreements mainly imply a limitation on the subsidized exports of cheese, we explicitly include this constraint in all the analyzed scenarios. In this paper, we cannot present the detailed results; however, we mainly show that the best scenarios are the ones which include a decrease in the level of milk quota. These scenarios lead to a higher increase in the social welfare but also to a lower decrease in the producers' surplus as the decrease in the price of milk (due to the reduction in the exports of cheese) is partly compensated by the positive effects on prices implied by the decrease in the milk production. Finally, the social welfare increases because the distortions on prices are smaller and moreover, they concern a smaller level of production. The recent proposal of the EC consisting in cutting down the intervention prices of butter and skim milk powder by 15% coupled with an increase in the level of milk quota leads to a large decrease in the price of milk. Such a reduction in the price of milk implies a dramatic decrease in the producers' surplus. Thus, direct payments are needed in order to compensate (or partly compensate) producers. However, if the opportunity cost of public funds is positive, this policy will quickly leads to a decrease in the social welfare.

5 - Conclusion

In the short term, the partial equilibrium model is a good framework for analyzing the impact of the various instruments of economic policy used in the dairy industry. Particularly, it

emphasizes the interactions between the various markets as a result of the multi-production and the joint production of the intermediate products in this processing industry. For instance, a reduction in the price of butter leads to a decrease in the production of butter and skim milk powder but to an increase in the production of cheese. Similarly, a reduction in the level of unit export refunds on cheese implies a decrease in the exports of cheese but an increase in the exports of butter and skim milk powder. Thus, to adjust the exports to the export constraints defined by the GATT, some engagements on the exports of other products can then be reached. This is a convincing argument for taking the processing stage explicitly into account. More aggregated models do not distinguish the various final products. They are therefore inadequate for explaining these interaction mechanism between markets, which, in practice, is very important for analyzing scenarios of European dairy policy.

The model may be improved in different ways. First, we could formally evaluate the effect of other scenarios of agricultural policy, combining the interventions on prices, milk quotas and unit export refunds. From a methodological point of view, it would be interesting to take into account the presence of imperfect competition in some markets (for instance, the cheese market is a market of differentiated products).

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