Modelling Agricultural Abandonment: The Agri-Environmental Regulation Revisited

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Abstract

The article analyzes some regulatory mechanisms preventing agricultural abandonment by the introduction of some particular changes in the marginal benefits of farming. Two farming methods are considered: intensive and extensive. When the authors analyze the policy recovering the abandoned land with intensive farms they conclude that there exists a decoupled policy that maintains constant the agricultural revenue without any regulatory cost. When the authors analyze the policy recovering the abandoned land with extensive farms they conclude that recovering the abandoned land necessary requires the implementation of partial decoupled policies. The completely decoupled policies in the model require the substitution of intensive with extensive farms, and so the increase of the regulatory funds.

Keywords: CAP, land abandonment; multifunctional agriculture; public policy, rural development.

Introduction

Since several years, the issues of de-coupling agricultural support are at the core of the international negotiation on trade and shape the public intervention in agriculture. Lastly, during the Luxembourg agreement in June 2003, French government was a major opponent of full decoupling and shared the opinion that partial de-coupling is the main instrument to keep agricultural activities that is recognized as the principal factor of the vitality of the rural areas. French position was then followed by a majority of Member States. The CAP reform of June 2003 stipulates: "in order to avoid abandonment of production, Member States may choose to maintain a limited link between subsidy and production (European Commission, 2003)".

Baldock et al. (1996) have identified the vulnerability to abandonment of extensive farming regions and those where small-scale farming is prevalent. These regions include most of Spain,

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large areas of southern France, parts of the UK, Ireland and Italy. They concern about 30% of the utilized agricultural areas but only around 15% of agricultural holdings. The abandonment of the agricultural activities in these regions has then economic and social impacts that go beyond the agricultural sector and important ecological and environmental consequences (CEC, 1997).

Agricultural adjustment may reduce the risk of land abandonment by maintaining the viability of the farm business. Many possibilities are opened to the farmers: pluriactivity, technical change, onfarm diversification (Dax et al., 1995). Adjustment reflects the opportunities available. Macdonald et al. (2000) found that for 21 out of 24 zones located in mountainous region of Europe they studied intensification occurs in conjunction with abandonment which clearly has potential for undesirable impacts on the environment. On the other hand, the experiment of the agri-environmental contracts in France shows the weakness and limits of available instruments in managing underprivileged rural areas. Then, the objective of this paper is to revisit the various forms of public regulation that allow one to prevent agricultural abandonment.

In our model we consider two types of farming methods that are different in land-use intensity. It is supposed that the extensive farming method enhances environment and labour and makes use of much more surface than the intensive. However, the intensive farms provide more benefits than the extensive. We consider then that the profitability of the extensive use of land decreases into a point in which agricultural abandonment is unavoidable. Next we present some proposals of regulation that are graphically illustrated by the confrontation of the marginal benefits of farming, as in Guyomard and Mahé (1995) or also LeGoffe (2003).

In particular, we introduce the analytical description of the model in the section 1. Then we analyze two alternative settings of public intervention. In the section 2 we consider the regulation rewarding the most profitable farms, which are supposed to be profitable enough to support rural development. The section 3 is devoted to the analysis of the policies regulating the extensive farming method, according to the relevant strategy of the recent CAP reforms (EC 2003, Rizov 2004). In the section 3.1 we consider the accurate recovering of the abandoned land with null regulatory funds; that is by the redistribution of the agricultural revenue of the extensive farms. In the section 3.2 we analyze the incentive policy supporting the agricultural revenue of the extensive farms. Next, the section 3.3 presents and discusses the relevance of the decoupled policies preventing agricultural abandonment.

1. The model

1.1. The Starting Point

As mentioned before, we consider two types of farming methods that are conform environmental but different in land-use intensity. The extensive farms (denoted by the index *e*) enhance environment and make use of much more surface than the intensive (denoted by the index *i*). The contribution of the first to rural development is highly relevant. However, since direct agricultural externalities on rural development are not internalized, the extensive farms provide less benefits than the intensive. In our model the total agricultural surface in the economy is normalized to *1*. We denote by s the agricultural surface allocated to the intensive or the extensive farms. The private benefits here considered are made up of linear income and quadratic costs. In particular, the private benefits follow the specification below:

$$B = p \cdot r \cdot s - c \cdot \frac{s^2}{2} \tag{1}$$

where r denotes the yield of land (i.e. the *output per hectare*) and c specifies the cost of farming depending on the quadratic surface. The prices in the model are constant and equal to the unit: $p = 1$ (in *euro per unit of output*). Notice that as a consequence the output and the income are equivalent and equal to the product $r \times s$.

We confront the extensive to the intensive marginal benefits in the same figures. In fact, we present the marginal benefits of the intensive farms on the opposite y-axis to the extensive farms. That is the case in Guyomard and Mahé (1995) and in the usual model of externalities (Baumol and Oates, 1988). Let us consider any figure in the article, for example the figure 1: for any s hectares allocated to the extensive farms (on the left y-axis) there are $(1 - s)$ hectares allocated to the intensive (on the right y-axis). Then the marginal benefits of the extensive and the intensive farms are rewritten as follows, respectively:

$$\begin{cases} BM_e = r_e - c_e s \\ BM_i = c_i s - (c_i - r_i) \end{cases} \tag{2}$$

We denote by s_e (or s_i) the intersection point of the marginal benefits BM_e (or BM_i) and the x-axis:

$$s_e = \left(\frac{r_e}{c_e}, \quad 0 \right) \qquad s_i = \left(\frac{c_i - r_i}{c_i}, \quad 0 \right) \tag{3}$$

The cartel of intensive farms requires then s_i hectares to maximize the private benefits, while the extensive require s_e hectares, as it can be seen in the figure 1. The optimal benefit in both cases corresponds with the triangular surfaces *s_iÅ~1Å~r_i* and *0Å~s_eÅ~r_e*. As we have mentioned before, the extensive farms obtain lower benefits than the intensive, so that the following constraint arises:

$$\frac{r_e^{\,2}}{c_e} < \frac{r_i^{\,2}}{c_i} \tag{4}$$

Since the extensive farms make use of much more land than the intensive the condition $s_e > (1 - s_i)$ arises. On the other hand we consider that there is not any land set aside. That means the regulator seeks the accurate recovering of abandoned land. Then, since the total surface is normalized to 1, the condition $s_e + (1 - s_i) > 1$ also arises. The both preceding conditions allow us to write the constraint below:

$$\frac{r_e}{c_e} \in \left(\frac{1}{2}, 1\right) \qquad \frac{r_i}{c_i} \in \left(1 - \frac{r_e}{c_e}, \frac{r_e}{c_e}\right) \tag{5}$$

Let us consider now the figure 1. Forget, for the instance, the meaning of the parameter C. The trade off between the intensive and the extensive use of the land characterizes the starting point of the model. Notice that there is competition in the use of land when the analytical condition $s_e > s_i$ arises. The optimal allocation of the land corresponds with the intersection point of the marginal benefits, denoted by s^*. In this instance there is not agricultural abandonment still.

1.2. *The agricultural abandonment*

The European agricultural context has evolved from the starting point described in the preceding section to a very different point. In fact, nowadays the particular feature of the European agricultural context is not the trade off in the use of land but the abandonment of agricultural land. With regard to the model, we consider that the profitability of the extensive use of the land decreases to the point in which agricultural abandonment is unavoidable and farmers are required to leave aside some land in order to maximize their private profits. We introduce in the model a lumpsum cost, denoted by C, which determines the threshold of profitability from which some land is abandoned. We suppose that C reaches, at least, the profitability threshold in s_i as writing below according to the equation (3):

$$C > \frac{r_e c_i + r_i c_e - c_e c_i}{c_i} \tag{6}$$

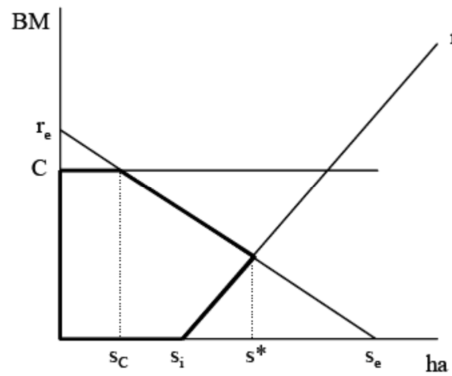

Figure 1. The agricultural abandonment

This is the relevant case described in the figure 1, where the low profitability of the extensive use of land keeps away the optimal equilibrium s^*, which is now unattainable. As a consequence the surface of the intensive farms increases up to the point s_i. The low profitability of the extensive use of land reaches a break point denoted by s_C.

$$s_C = \left(\frac{r_e - C}{c_e}, \quad 0 \right) \tag{7}$$

In particular there are $(s_i - s_C)$ hectares of abandoned land. It is supposed that these are the less suitable farms to produce agricultural commodities in both the extensive or intensive ways.

The figure 1 illustrates the lack of profits due to the weak profitability of the extensive farming method. The agricultural abandonment is responsible for the loss in the grass polygon, in which the cost *C* Å~ s_C is included. We also consider that the agricultural abandonment $(s_i - s_C)$ causes a negative externality that highly depends on the total deserted area, as mentioned before, and forces the intervention of the regulator.

In the next proposition we summarize the relationship between the relevant points to which we will refer in the following pages. In particular we bound the parameters in the model in order to define the context of agricultural abandonment we have described before. The proof is given the appendix A.

Proposition 1 *Let us consider the extensive and the intensive farming methods defined by the equations (2), (4) and (5). There is agricultural abandonment when the equation (6) arises. Then the following conditions have to be considered:*

$$c_i > r_i > r_e > C > 0 \qquad \text{and} \qquad c_i > c_e > r_e > 0{,}5 \cdot c_e > 0$$

From here on we consider that the preceding analytical conditions stand.

2. The regulation of the intensive farms

The intuitive solution to agricultural abandonment lies in regulating the intensive farms. In fact, farmers may expect a policy rewarding the most profitable farms with the argument that these are able to support rural activities and to enhance development.

In our model the regulator resolves to prevent the agricultural abandonment *(s_i - s_C)* with incentive policies. In particular, he proposes an incentive mechanism that modifies the marginal benefits of the intensive farming method (equation 2) in the following way:

$$BM_i = (c_i + \sigma_i)s - ((c_i + \sigma_i) - (r_i + \tau_i)) \quad (7)$$

This regulatory mechanism takes the form *($\tau_e\, s - 0{,}5\ \sigma_e\, s2$)* according to the private benefits of the intensive farms in equation (1). Indeed, the parameters τ_i and σ_i defining the regulatory mechanism verifies the equilibrium between the two farming methods. An allocation of the land is at the equilibrium when the marginal benefits of the extensive and the intensive farming methods are equivalent:

$$r_{e-}\ c_e s_{opt} - c = (c_i + \sigma)s_{opt} - ((c_i + \sigma_i) - (r_{i+\tau})) \quad (8)$$

In addition to the preceding condition, the policy maker takes into account the regulatory funds (denoted by F) and the variation of the agricultural output (denoted by D). Remind that the regulator looks for the maximal decoupling policy. According to the OECD (2001) **a regulatory policy is decoupled when the output remains constant**. Following this argument the regulatory mechanism in this section is completely decoupled while the equation (10) remains null:

$$F = \int_{s_{opt}}^{1} \{\sigma_i s - (\sigma_i - \tau_i)\} ds \quad (9)$$

$$D = s_{opt}(r_e - (r_i + \tau_i)) - s_C r_e + s_i r_i + \tau_i \quad (10)$$

Finally the regulatory mechanism is constraint by the minimal variation of the agricultural revenue. The equations below define the *ex ante* and the *ex post* benefits, respectively:

$$B_{initial} = \int_0^{s_C} \{r_e - c_e s - C\} ds + \int_{s_i}^{1} \{c_i s - (c_i - r_i)\} ds \quad (11)$$

$$B_{final} = \int_0^{s_{opt}} \{r_e - c_e s - C\} ds + \int_{s_{opt}}^{1} \{(c_i + \sigma_i)s - ((c_i + \sigma_i) - (r_i + \tau_i))\} ds \quad (12)$$

Indeed, the revenue of the farmers remains constant when the regulatory mechanism verifies the condition (11) = (12).

Let us consider now the first best allocation recovering agricultural abandonment. The optimal policy must propose a decoupled solution to agricultural abandonment while the regulatory funds are null and the agricultural rent remains constant. As we present in the following proposition, such a solution is possible but it requires the substitution of the abandoned land with intensive farms. However, at the same time, the regulatory mechanism modifies the productivity of the intensive farming method. In particular, the yield of the intensive use of land reduces. This regulatory mechanism makes more homogeneous both farming methods and so may contribute to expand the extensive use of land by changing the intensive yield of land. The proof is given in the appendix B.

Proposition 2 *For every cost C the optimal allocation of the land solving the agricultural abandonment without variation of the rent corresponds with the point* s_C *. In this case the regulation is decoupled, the regulatory cost is null and the rent of the farmers remains constant.*

In the figure 2 we illustrate the first best solution to the agricultural abandonment when the regulator implements an incentive policy on the intensive farming method. As it can be seen, the optimal allocation of the land requires the enlargement of the intensive use of land from the point s_i to s_C. Notice that the total output and the rent of the farmers remain constant and how the regulatory funds are null. Notice also that the intensive yield of land decreases.

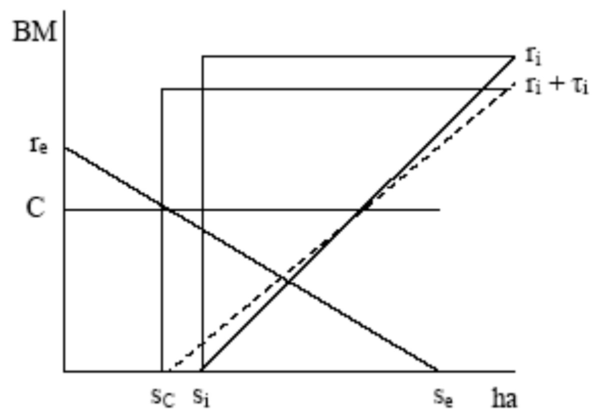

Figure 2. The regulation of intensive farms

3. The regulation of the extensive farms

3.1 The regulation without cost

Let us consider in this section a different approach to the regulation of the agricultural abandonment. As known, the CAP reforms promote the "environmentalization of the agricultural policy" (Buttel, 1994). In this respect, the link between the extensive farming and the environment is relevant. Cummings (1990) asserts that a "pattern of land use has being established throughout the EU, whereby a category of productive farmers co-exists with a growing proportion of holdings that must be allocated other roles as resource managers in the rural economy (in Rizov 2004)".

With regard to our model, we consider the implementation of an incentive policy that modifies the marginal benefits of the extensive farming method in the following way:

$$BM_e = (r_e + \tau_e) - (c_e + \sigma_e)s \qquad (13)$$

This incentive mechanism takes the form *(τ_e s – 0,5 σ_e s2)* according to the private benefits of the extensive farms in equation (1). In this section we analyze the regulation without cost. That means the regulator is determined to solve agricultural abandonment by redistributing the whole revenues of farming; that is without making use of any regulatory funds. In this instance, the parameters τ_e and σ_e defining the incentive mechanism have to verify some particular conditions. First, the optimal allocation has to verify the equilibrium between the two farming methods, as mentioned before. Second, the regulatory funds have to be null: *F = 0*. Both conditions are written, respectively, as follows:

$$(r_e + \tau_e) - (c_e + \sigma_e)s_{opt} - C = c_i s_{opt} - (c_i - r_i) \qquad (14)$$

$$F = \int_0^{s_{opt}} \{\tau_e - \sigma_e s\} ds \qquad (15)$$

Remind also that the optimal equilibrium has to be at least equal to s_i in order to prevent agricultural abandonment. Finally, remind also that the regulatory mechanism is completely decoupled when the equation *D = 0* stands:

$$D = s_{opt}(r_e + \tau_e - r_i) - s_C r_e + s_i r_i \qquad (16)$$

When solving the simultaneous equations (14) and (15) a threshold in the profitability of the extensive use of land is found:

$$C^* = r_e - s_i c_e \qquad (17)$$

In fact, the regulatory cost of the incentive mechanism is null only if $C < C^*$. In other words, when the profitability of the extensive use of the land is too weak the un-costly regulation of the agricultural abandonment is unattainable. Then, the regulator undertakes to allocate some funds in order to prevent abandonment. Furthermore the output increases with the surface *s* while the revenue decreases. In every case, the optimal allocation of the land corresponds with the point s_i. We present the solution in the proposition below. The proof is given in the appendix C.

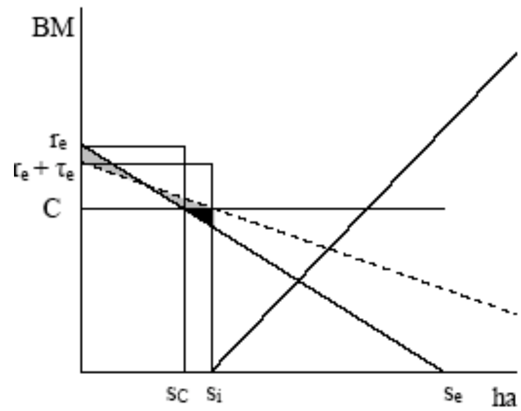

Figure 3. The regulation without cost

Proposition 3 *When $C < C^*$ the optimal allocation of the land solving the agricultural abandonment without cost corresponds with the point s_i. In this case the regulation is not decoupled (the output increases) and the rent of the extensive farms decreases. When $C > C^*$ the regulation without cost is unattainable.*

We illustrate the case $C < C^*$ in the figure 3. The incentive regulation transforms the initial BM_e function (continuous line) into a new BM_e function (discontinuous line). The new BM_e function prevents the agricultural abandonment $(s_i - s_C)$ and the regulatory funds are null. However, the agricultural rent diminishes and the output increases. This figure illustrates that the un-costly regulation of the agricultural abandonment is not decoupled and punishes the revenues of the extensive farms. Remark that the black surface, which corresponds with the decrease of the agricultural revenue, is included in the grey triangle on the right. Since both grey triangles are equivalent, the regulatory funds are null.

3.2 The regulation without variation of the agricultural rent

In this section we consider the regulatory mechanism that gives priority to the revenue of farming. The regulator resolves now to invest funds in order to prevent the agricultural abandonment under the constraint of constant agricultural revenue. He designs a regulatory policy that supports the private profits of the farmers with public funds and that respects the decoupled allocation defined in the equation (16).

In addition to the equation (14) defining the optimal equilibrium, the parameters τ_e and σ_e defining the regulatory mechanism verifies now the null variation of the agricultural revenue. In this instance the initial benefits of farming in the equation (11) and the final benefits in the equation below are equivalent:

$$B_{final} = \int_0^{s_{opt}} \{(r_e + \tau_e) - (c_e + \sigma_e)s - C\} ds + \int_{s_{opt}}^1 \{c_i s - (c_i - r_i)\} ds \quad (18)$$

Remind that the regulator seeks the minimal regulatory cost in equation (15) and also the maximal decoupling policy in equation (16). In the proposition below we present the whole solution in this case. The proof is given in the appendix D.

Proposition 4 *For every cost C the optimal allocation of the land solving the agricultural abandonment without variation of the rent corresponds with the point* s_i*. In this case the regulation is not decoupled (the output increases) and the regulatory cost increases with the surface s.*

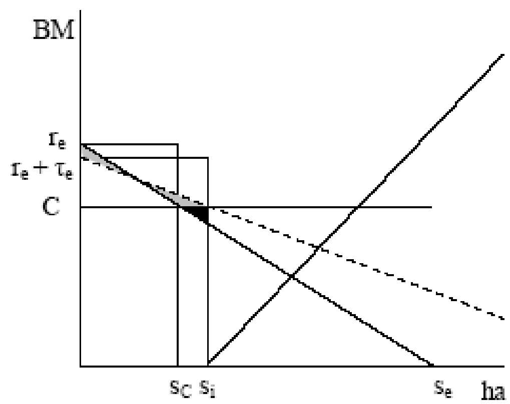

Figure 4. The regulation without rent variation

The figure 4 illustrates the regulation without variation of the agricultural rent. Notice a relevant difference with respect to the figure 3: the new BM_e function in the figure 4 (discontinuous line) maintains the revenue of the farmers thanks to the regulatory funds, which are positive. In both figures the incentive mechanisms prevent the agricultural abandonment *(s_i - s_C)* with partial decoupling (the output increases). Furthermore, both the degree of decoupling and the regulatory cost increases with the cost *C* and the surface *s*. In this instance the black surface, which corresponds with the net regulatory funds, is not included in the grey triangle on the right. Since the grey triangles are equivalent the revenue of the farmers remains constant.

3.3 The decoupled reallocation of farming

In this section we analyze the decoupled regulation of the extensive farming. Thus, the agricultural output remains constant after the implementation of the policy recovering the agricultural abandonment.

Let us forget for the moment the cost of the incentive mechanism in the equation (13). Consider the equation (14) defining the equilibrium between the two farming methods and the equation (16) defining the decoupled policy $D = 0$. A threshold in the profitability of the extensive use of the land, denoted by C^{**}, is found when these simultaneous equations are solved. When the lack of profitability of the extensive use of land is too much high the decoupled equilibrium is not achievable.

$$C^{**} = \frac{r_e^{\,2}}{r_e + c_e s_i} \tag{19}$$

Proposition 5 *When $C < C^{**}$ the optimal allocation of land solving agricultural abandonment in the decoupled manner verifies the following condition:*

$$s_{opt} \in \left(s_i, \frac{c_i - C + \sqrt{(C - c_i)^2 + 4c_i(r_e s_C - r_i s_i)}}{c_i} \right)$$

When $C > C^{**}$ the decoupled regulation is not possible.

The result in the proposition above means that the decoupled regulation requires the substitution of intensive with extensive farms. Furthermore there is a continuum set of decoupled allocations that prevents abandonment. The regulatory cost and the agricultural revenue increase when the substitution of intensive with extensive farms enlarges. The proof is given in the appendix E.

In fact, when the profitability of the extensive farms is high enough the optimal allocation of land requires the substitution of the less profitable among the intensive farms with extensive. As a consequence, the output reduces (remind that the yield per intensive hectare is higher than the yield per extensive: $r_i > r_e$). However, on the other hand the output increases because of the production of the farms in $(s_i - s_C)$, which otherwise were abandoned. The regulatory mechanism in equation (13) is designed such as the whole output remains constant.

Let us introduce now in the model the cost of the regulation. When the equation (15) is considered in addition to the equation (14) defining the equilibrium and to the equation (16) defining the decoupled policy, the optimal allocation of the land, denoted by s_{d1}, verifies $s_{d1} > s_i$. On the other hand, the decoupled allocation verifying the constant revenue constraint (11) = (18) is denoted by s_{d2} and it is also higher than the maximal allocation of intensive farming.

In this point, some interesting results arise when the cost of the regulation and the variation of the agricultural rent are introduced in the model. In fact, we can affirm in the first time that the decoupled regulation is achievable without cost, and also with constant revenue. Nevertheless, there is not any decoupled regulation of the extensive farms that verifies both the null cost and the constant revenue constraints. The proof of the proposition below is given in the appendix E.

Proposition 6 *Let us consider $C < C^{**}$, then the extensive surface allocated by the decoupled regulation with null cost is lower than the extensive surface allocated by the decoupled regulation with constant revenue: $s_{d1} < s_{d2}$. Both the regulatory funds and the agricultural revenues increase with the surface s.*

In other words, the regulator has a continuum of incentive policies solving abandonment. In particular, for any allocation on the interval (s_i, s_{d1}) the regulator enjoys a negative subsidy and consequently the rent of the farmers diminish. The cost of the regulation is positive and the variation of the agricultural rent is negative for any allocation of the land on the interval (s_{d1}, s_{d2}). Finally, for 9 any allocation on the interval $(s_{d2}, s_{opt\ MAX})$ both the cost of the regulation and the agricultural revenue are positive.

In the figure 5 we compare the decoupled regulation when the regulatory funds are null (figure on the left) with the decoupled regulation when the agricultural revenue remains constant (figure on the right). The dotted lines correspond with the marginal benefits of the extensive farms when the incentive mechanism is implemented. Remark that the surfaces a_1 and b_1 are equivalent, so the regulatory funds are null. The revenue of the farmers in the figure on the left decreases in a quantity equivalent to the black surface minus the decrease of the intensive benefits. Remark also that the shadow surfaces verifies the condition $a_2 - b_2 + c = 0$. In other words, the revenue of the farmers remains constant. Since $a_2 < b_2$ the regulatory funds are positive.

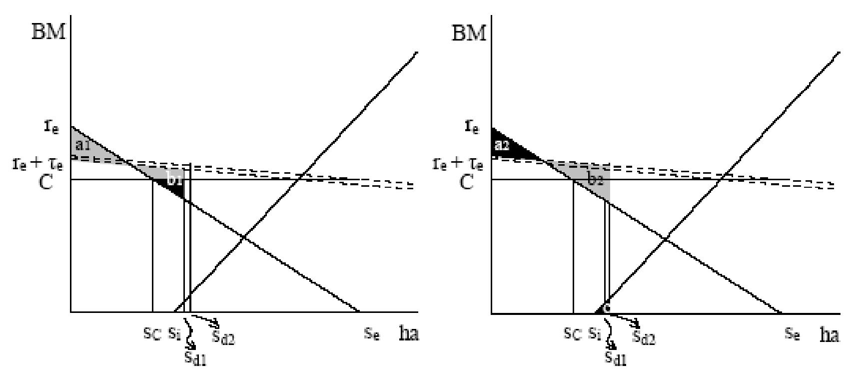

Figure 5. The decoupled regulation

6. Conclusions

It is well known that the European agricultural context has been evolving into an integrated sector with environmental and rural development objectives. Agricultural abandonment has arisen a relevant point. In this model the authors analyze some regulatory mechanisms that prevent agricultural abandonment by the introduction of some particular changes in the marginal benefits of farming. The authors consider that the regulator seeks the maximal decoupled policy at the minimum cost and without reduction of the agricultural revenue.

First the authors analyze the policy recovering the abandoned land with intensive farms. They conclude that the first best solution is achievable. Thus, there exists a decoupled policy that maintains constant the agricultural revenue without any regulatory cost. In this case the yield of land of the intensive farms reduces. However the enlargement of intensive farming does not seems the relevant strategy according to the recent CAP reforms.

Second the authors analyze the policy recovering the abandoned land with extensive farms. They conclude that recovering the abandoned land necessary requires the implementation of partial decoupled policies. The completely decoupled policies in the model require the substitution of intensive with extensive farms. The regulator enjoys then a continuum set of decoupled allocations that prevent abandonment. Nevertheless, the regulatory cost (and so the agricultural revenue) highly increases when the substitution of intensive with extensive farms enlarges.

When the authors analyze the substitution of intensive with extensive farms they conclude that the decoupled allocation of land preventing abandonment is achievable without cost, and also with constant agricultural revenue. Nevertheless, there is not any decoupled policy verifying both the constraints at the same time.

Appendices

A) The parameters of the model according to agricultural abandonment

Let us consider the constraints in the equations (4) and (5). Then we have necessarily $r_i > r_e$ and $c_e < c_i$. Remind then that $s_e \in (0,1)$ and $s_i \in (0,1)$, so that we also have necessarily $r_i < c_i$ and $r_e < c_e$. The equation (5) allows us to affirm that the inequality $r_e > 0{,}5\ c_e$ always happens. When there is agricultural abandonment the yield of the extensive use of land is binding with respect to the threshold C in the equation (6). So that the following inequalities arise: $c_i > r_i > r_e > C$ and $c_i > c_e > r_e$.

B) The regulation of the intensive farms

Let us consider the marginal benefits in the equation (7). The allocation s_C verifies the decoupled constraint $D = 0$ in the equation (10) when the incentive mechanism verifies the condition below:

$$\tau_i = \frac{r_i(s_C - s_i)}{1 - s_C} \qquad \text{(1B)}$$

We obtain the complete incentive mechanism by the equation (1B) and the equilibrium constraint in equation (8):

$$\sigma_i = \frac{r_i(1 - s_i)}{(1 - s_C)^2} - c_i \qquad \text{(2B)}$$

The equations (1B) and (2B) make null the regulatory funds in the equation (9).

C) The regulation without cost

Let us rewrite the equation (14) defining the equilibrium between the two farming methods and the equation $F = 0$ in (15) defining the absence of regulatory funds, respectively:

$$s_{opt} = \frac{r_e - r_i + c_i + \tau_e - C}{c_i + c_e + \sigma_e} \qquad \text{(1C)}$$

$$s_{opt} = \frac{2\tau_e}{\sigma_e} \qquad \text{(2C)}$$

When the simultaneous equations (1C) and (2C) are solved the following result is found:

$$s_{opt} = \frac{r_e - r_i + c_i - \tau_e - C}{c_i - c_e} \qquad \text{(3C)}$$

The condition $s_{opt} = s_i$ is necessary to retrieve agricultural abandonment, so the preceding equation is rewritten as follows:

$$\tau_e = r_e - C - s_i c_e \qquad \text{(4C)}$$

The new marginal benefit after implementation of the policy has to verifies $r_e + \tau_e > C$ in order to make profitable the extensive farms. Remind that there is abandonment when $s_i > s_C$, so:

$$C \in \left[r_e - s_i c_e , r_e - \frac{s_i c_e}{2} \right] \qquad (5C)$$

Then it is found $\tau_e < 0$, by the equations (4C) and (5C). It is also found $\sigma_e < 0$, by the equation (2C):

$$\tau_e \in \left[-\frac{s_i c_e}{2}, 0 \right] \qquad \sigma_e \in \left[-c_e, 0 \right] \qquad (6C)$$

In short, when the equation (5C) stands the regulation without cost verifies the simultaneous equations below:

$$\begin{cases} s_{opt} = s_i \\ \sigma_e = 2\left(\dfrac{r_e - C}{s_i} - c_e \right) \\ \tau_e = r_e - C - s_i c_e \end{cases} \qquad (7C)$$

Let be the equations defining the output of the extensive farms before and after the regulation, respectively:

$$\begin{cases} D_0 = r_e s_C \\ D_1 = (r_e + \tau_e) s_i \end{cases} \qquad (8C)$$

The equation (4C) and the definition of s_e and s_C, in the equations (3) and (7) respectively, assure that the variation of the output ($D_1 - D_0$) increases with C. Since the output remains constant at the minimum C in the equation (5C), we can affirm that the output increases when the profitability of the extensive farms reduces.

Let be the equations defining the revenue of the farmers before and after the regulation, respectively:

$$\begin{cases} F_0 = \dfrac{s_C (r_e - C)}{2} \\ F_1 = \dfrac{s_i (r_e + \tau_e - C)}{2} \end{cases} \qquad (9C)$$

Notice that in both cases the revenue decreases with C. Since the variation of the revenue ($F_1 - F_0$) remains constant at the minimum C in the equation (5C), we can affirm that the revenue decreases when the profitability of the extensive farms reduces.

D) The regulation without variation of the agricultural rent

Let us rewrite the equation (14) defining the equilibrium between the two farming methods and the equation ($F_1 = F_0$) in (9C), respectively:

$$s_{opt} = \frac{r_e - r_i + c_i + \tau_e - C}{c_i + c_e + \sigma_e} \tag{1D}$$

$$\tau_e = (s_C - s_i)(r_e - C) \tag{2D}$$

Notice that $\tau_e < 0$ by the proposition 1 (see the appendix A), and so $\sigma_e < 0$. Remind that $s_{opt} = s_i$ is necessary to retrieve agricultural abandonment. The new marginal benefit after implementation of the policy always verifies $r_e + \tau_e > C$, by the equation (2D) and the Proposition 1:

$$C \in [r_e - s_i c_e, r_e] \qquad \tau_e \in [(s_C - s_i)s_i c_e, 0] \qquad \sigma_e \in [-c_e, 0] \tag{3D}$$

In short, when the equation (5C) stands the regulation without cost verifies the simultaneous equations below:

$$\begin{cases} \sigma_e = c_e\left(\dfrac{s_C{}^2}{s_i{}^2} - 1\right) \\ s_{opt} = s_i \\ \tau_e = \dfrac{(r_e - C)(s_C - s_i)}{s_i} \end{cases} \tag{4D}$$

Let be the equations defining the output of the extensive farms before and after the regulation, respectively:

$$\begin{cases} D_0 = r_e s_C \\ D_1 = (r_e + \tau_e)s_i \end{cases} \tag{5D}$$

The equation (2D) and the definition of s_e and s_C, in (3) and (7) respectively, assure that the variation of the output ($D_1 - D_0$) increases with C. Then we can affirm that the output increases when the profitability of the extensive farms reduces.

Let us rewrite the equation defining the regulatory funds according to the preceding results:

$$F = (r_e - C)(s_C - s_i) + c_e \frac{s_i^2 - s_C^2}{2} \qquad (6D)$$

Notice that F increases with *C*:

$$\frac{dF}{dC} = s_i - s_C > 0 \qquad (7D)$$

Since F is null at the minimum *C* in the equation (3D), we can affirm that the regulatory funds increase when the profitability of the extensive farms reduces.

E) The decoupled equilibrium

Let us rewrite the equation (14) defining the equilibrium between the two farming methods and the equation *D = 0* in (16) defining the decoupled policy:

$$s_{opt} = \frac{r_e - r_i + c_i + \tau_e - C}{c_i + c_e + \sigma_e} \qquad (1E)$$

$$s_{opt} = \frac{s_C r_e - s_i r_i}{r_e - r_i + \tau_e} \qquad (2E)$$

When the preceding simultaneous equations are solved the following result is found:

$$\tau_e = r_i - r_e + \frac{r_e s_C - r_i s_i}{s_{opt}} \qquad (3E)$$

$$\sigma_e = \frac{r_e s_C - r_i s_i - s_{opt}[C - c_i + (c_e - c_i)s_{opt}]}{s_{opt}^2} \qquad (4E)$$

Let us introduce now the constraint $\sigma_e \geq -c_e$, which assures the negative slope of the new marginal benefits. By the equation (4E) we obtain the upper bond of the optimal allocation:

$$s_{opt} \in \left(s_i, \frac{c_i - C + \sqrt{(C - c_i)^2 + 4c_i(r_e s_C - r_i s_i)}}{c_i} \right) \qquad (5E)$$

Remind also that the constraint $r_e + \tau_e > C$ stands. By the equations (3E) and (5E) it is found a threshold in the profitability of the extensive use of land. The decoupled policy has to verify the following condition:

$$C \leq \frac{r_e^{\,2}}{r_e + c_e s_i} \qquad (6E)$$

Notice that the upper bond of the decoupled allocation (equation 5E) decreases with C. The decoupled allocation stands at s_i when C is minimal.

F) Decoupling, regulatory funds and agricultural rent

Let us consider the equation defining the regulatory funds:

$$F = s_{opt}\left(\tau_e - \frac{\sigma_e}{2} s_{opt}\right) \qquad (1F)$$

The equations (3E) and (4E) allow us to affirm that F increases with s_{opt}. Then the revenue in equation (18) necessary increases. When checking the variation of the revenues at the point s_{d1} (see s_{opt} in the equation 2C) it is obtained that the revenue of the farmers decreases. So we have necessary $s_{d1} < s_{d2}$.

References

Baldock D., Beaufoy G., Brouwer F. and Godeschalk F. (1996): *Farming at the Margins: Abandonment or Redeployment of Agricultural Land in Europe*, Institute for European Environmental Policy Agricultural Economics Research Institute, London/The Hague.

Baumol and Oates (1988): "The theory of environmental policy", Cambridge University Press, Second edition.

Bima 1502 (2003): "La nouvelle politique agricole commune – Accord de Luxembourg".

Buttel (1994): "Agricultural change, rural society and the state in the late twentieth century – Some theoretical observations", in Symes and Jensen (eds.): *Agricultural restructuring and rural change in Europe*, Wageningen: Agricultural University.

CEC (1997): *Rural Developments* CAP 2000 Working Document, Commission of European, Communities, DG VI, Brussels.

Cummins (1990): "Restructuring agriculture in advanced societies: transformation, crisis and responses", in Marsden, Lowe and Whatmore (eds.): *Rural restructuring: global processes and their responses*, London, David Fulton Publishers.

Dax T., Loibl E. and Oedl-Wieser T. (1995): *Pluriactivity and Rural Development*, Research Report No. 34, Bundesanstalt fur Bergbauernfragen, Vienna.

European Commission (2003): "EU fundamentally reforms its farm policy to accomplish sustainable farming in Europe" (http://www.europa.eu.int/comm/agriculture/mtr/index-en htm).

Guyomard and Mahé (1995): "La nouvelle instrumentation de la politique agricole commune", Economie et prévision.

Le Goffe (2003): "Multifunctionnalité des prairies: comment articuler marché et politiques publiques", INRA Productions Animales

MacDonald D., Crabtree J.R., Wiesinger G., Dax T., Stamou N., Fleury P., Gutierrez Lazpita J. and Gibon A. (2000): "Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response", *Journal of Environmental Management*, 59 (1), May 2000: 47-69.

OECD (2001): *The Challenge of Decoupling Agricultural Support*.

Rizov M. (2004): "Rural development and welfare implications of CAP reforms", *Journal Policy Modelling*.