

**ENVIRONMENTAL GOOD PRODUCTION
IN THE OPTIMUM ACTIVITIES PORTFOLIO
OF A RISK AVERSE FARMER**

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ENVIRONMENTAL GOOD PRODUCTION IN THE OPTIMUM ACTIVITIES PORTFOLIO OF A RISK AVERSE FARMER

Abstract

An analytical framework is proposed for analysis of environmental good production by farmers in the case of price uncertainty. Environmental good production contracted by means of agri-environmental agreements is treated as a riskless option in the farmer's production activities portfolio. Efficient frontiers were generated using mathematical programming farm level models of suckler cow farms in *Monts du Cantal*, in France. It was demonstrated that for a DARA risk averse farmer: 1) the agreement payment level is not without impact on the farming intensity on parcels not subscribed under the corresponding agri-environmental programme, 2) a lump sum payment matters under uncertainty, 3) the overall impact of the lump sum payment on environmental good production depends on the type of jointness in production of agricultural and environmental goods, and on the level of uncertainty.

Keywords: uncertainty, portfolio optimisation, biodiversity, agricultural policy, mathematical programming

JEL: Q12, Q18, Q28

1. Introduction

The Common Agricultural Policy (CAP) reform of June 2003 follows the trend of “decoupling” agricultural subsidies from production activities with the aim to fulfil the WTO commitments requiring application of less trade distorting agricultural policy instruments. Progressive reduction of the price support and of coupled subsidies, which accompanies this reform, is likely to increase the price volatility of agricultural outputs. As Hennessy (1998) demonstrated, under uncertainty even decoupled subsidies influence behaviour of a risk averse farmer. Thus it seems meaningful to apply models which enable to account for uncertainty and for farmers' risk aversion if analysing agricultural policies. In this paper, we propose such a framework for analysis of environmental good production by farmers when contracted by means of agri-environmental agreements.

Uncertainty is an important issue concerning the joint production of agricultural and environmental goods. Vermersch (2001) considers uncertainty as a special source of jointness. Hanley and Oglethorpe (1999) support indirectly this concept when they state that the guaranteed nature of agri-environmental payments offered to UK farmers represented for them an important incentive to adopt these agreements “as a risk-reducing management tool”. In our paper we do not consider uncertainty as an independent source of jointness. We investigate rather how the volatility of output prices changes the willingness of farmers to comply with agri-environmental agreements if one or another of the main sources of jointness as defined by OECD (2001) is present: non-allocable inputs (complementary production) and allocable fixed inputs (competing production).

The joint production of agricultural commodities, beef, and an environmental good, grassland biodiversity, is investigated here. The quantity of biodiversity produced depends on the grassland management intensity. Usually some special level of farming activity is required and the quantity of biodiversity produced falls both if this level is not attained or if it is exceeded. For example Balent et al. (1998) found that in Pyrenees the species richness of pastures slightly increases when the dry mass consumption increases from 0.5 tonnes/ha/year to something more than 1 tonne/ha/year but above this value it starts to fall. The optimal level of beef production is not unique for all biotopes. Thus some fragile biotopes require only very low levels of beef production and the beef and biodiversity is generally *competing* in such zones. The competition is caused by the presence of an allocable fixed input: the grassland. It can be considered as allocable as it should be partially or completely diverted from beef production in order to secure biodiversity production. On the other hand, there are zones where biodiversity is permanently jeopardised by invasive species and it would be lost without sufficiently high management intensity. There the beef and biodiversity production are generally *complementary*. The source of complementarity is the presence of a non-allocable input: the cattle herd. An increase in the number of livestock units enables to produce at the same time more beef and more biodiversity. We chose to deal with grassland biodiversity production by suckler cow farms

precisely for this opportunity to analyse both complementary and competing agricultural and environmental good production.

We propose to analyse the environmental good production under uncertainty in the expected value – variance framework elaborated by Markowitz (1952). If a farmer has the possibility to produce several outputs, he will not only adjust the overall supply but also its structure in the search for an efficient portfolio of activities. We consider the application of the separation theorem described by Tobin (1958) in the financial theory framework. Tobin demonstrated that if both risky and riskless assets are available, the optimisation proceeds in two steps. Firstly, the optimum portfolio of risky assets is assembled, whose composition does not depend on the risk aversion of the investor. Secondly, the investor decides depending on his risk aversion which share of his money should be invested in the risky portfolio and which share should be held in the riskless asset. The Tobin's separation theorem was applied to analyse the farm diversification problem by Johnson (1967) who considered as a riskless option the land leasing in or out. He concluded that a strongly risk averse farmer will tend to lease out a share of his land in order to ensure a higher stability of returns, a risk neutral farmer will rather tend to lease in some additional land in order to increase his returns even if this will increase the volatility of the expected profit. Roche and McQuinn (2004) applied the same separation theorem to the analysis of the European Union's CAP reform of the June 2003. They found that a complete decoupling of agricultural subsidies will encourage farmers who choose to produce, to introduce in their portfolio of activities riskier products than before the reform.

Our model is based on the assumption that the agricultural commodities (different types of animals sold at various ages, fattened or lean, etc.) represent risky activities due to stochastic output prices - the unique source of uncertainty in the model. Environmental good production remunerated by means of agri-environmental agreements is considered as a riskless activity. This is justified by the fact that agri-environmental agreements propose a guaranteed annual payment to the farmer during several years (5, 10 or 20) in exchange for his compliance with instructions involved in the contract. These instructions include some restrictions on the farming activity and/or they demand additional tasks to be carried out. The farmer is remunerated for compliance with the instructions and not for the result of his compliance. Thus not only the amount of the payment is guaranteed but the farmer controls entirely also the respect of conditions implying the attribution of the payment for particular year. Applying Tobin's separation theorem, the impact of the possibility to subscribe an agri-environmental agreement on the shape of farmers' portfolio efficient frontiers can be assessed.

The model is tested by implementing a mathematical programming farm level model of a representative suckler cow farm in the *Monts du Cantal*, France. In this region, zones representing both complementary and competing beef and biodiversity production can be found in formally designated Environmentally Sensitive Areas (ESAs), where agri-environmental agreements were proposed to farmers in order to enhance the biodiversity production. A simplified version of these agreements from two selected ESAs is incorporated into the programming model in order to assess the validity of the theoretical framework and to derive comparative statics concerning the impact of decoupled subsidies and output price variability on the biodiversity production.

2. Analytical framework: Portfolio optimisation

The general framework is presented graphically here. We suppose that the farmer maximises a utility function $U=f(E(\pi),V(\pi))$ where $E(\pi)$ is the expected profit and $V(\pi)$ the standard deviation of profit. The E, V space contains two basic elements: the efficient frontier of risky assets and a set of farmer's indifference curves. All through the text we make the assumption that the farmers exhibit decreasing absolute risk aversion (DARA). DARA preference assumption is well supported by empirical studies carried out by Lins et al. (1981), Saha et al. (1994) or Chavas and Pope (1996). For DARA farmers, the marginal rate of substitution between the expected profit and its standard deviation decreases with expected utility of profit. The indifference map can be plotted as in Figure 1. We make another common assumption that the efficient frontier is concave. When no riskless activity exists, a utility maximising farmer will choose to produce the output bundle R, the tangency point between the efficient frontier and an indifference curve.

Agri-environmental agreements concerning biodiversity production demand from the farmer a decrease of the farming intensity if biodiversity production is competing for resources with beef production. An illustrative example are the environmental set asides where the farmer receives a payment for not using a part of his land for agricultural production. Thus he exchanges a part of the

risky income from agricultural commodities production for a guaranteed income from environmental good production.

If the possibility to divert a share of the land from beef to biodiversity production for a transfer payment t is introduced, the farmer can gain the sum T corresponding to the total number of hectares he possesses multiplied by the agreement payment t and reduced by fixed cost in the short run, without facing any risk. T is for him a certainty equivalent. We can draw a line representing linear combinations of the certainty equivalent and the risky activities bundle, corresponding to the market opportunity line in the finance theory. This line starts from the point T , and a utility maximising farmer will construct it so that it is tangent to the efficient frontier of risky activities, in our case the line TBA . Thus the optimisation really proceeds in two stages: firstly, the farmer determines the optimal risky output bundle, here A , as the tangency point between the market opportunity line and the efficient set of risky activities, and then the share of the land to be committed to the agreement, $|AB|/|AT|$, where B is the tangency point between the new efficient frontier and an indifference curve. The new efficient frontier accounting for the agri-environmental agreement is composed of two segments: the linear segment TA and the concave one corresponding to the original efficient frontier to the right of the point A .

This scheme enables us to discuss directly the impacts of a change in the agri-environmental payment t . If the agreement payment is increased from t to t' , the certainty equivalent increases from T to T' . The slope of the market opportunity line decreases and its tangency point with the indifference curve, D , corresponds to lower variability in comparison to the point B . On the other hand, the tangency point of the market opportunity line with the efficiency frontier, C , moves rightwards. Thus the share of land diverted from beef to biodiversity production unambiguously increases ($|CD|/|CT'| > |AB|/|AT|$). The profit variability of the bundle of risky activities indicated by the point C is higher than it was at the point A . If higher intensity implies higher uncertainty about the profits from risky agricultural activities, the land not committed to the agreement will be managed more intensively than before the increase in t . Thus risk aversion can partially explain the perverse effects of some environmental agreements which aiming on the extensification on one field induce undesirable intensification on others.

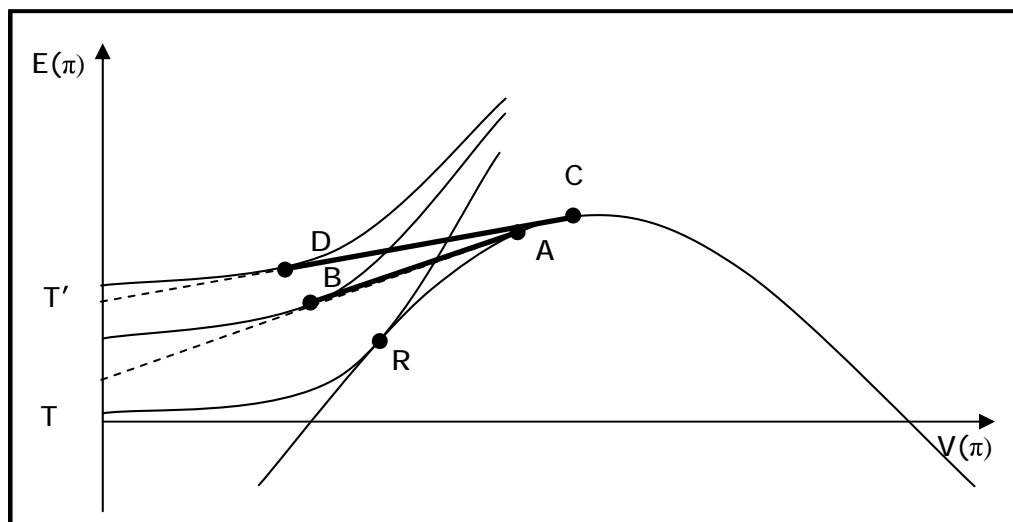


Figure 1. Tobin's separation theorem and the competing beef and biodiversity production.

The same framework can be applied for the case where beef and biodiversity production are complementary. Often the most valuable grasslands from the biodiversity point of view are being abandoned because their management is not profitable. The re-utilisation induces some costs due to the necessary shrub cleaning, renewal of the grassland or shrub prevention and some benefits in the form of supplementary forage. The agri-environmental payment serves to cover only partially the costs, the rest still has to be covered by the stochastic benefits from agricultural production.

The complementary beef and biodiversity production is depicted in the Figure 2. As in the scheme above, the optimum portfolio of activities if no agri-environmental agreements are proposed corresponds to the point R . But even without agreements the farmer can re-utilise his previously abandoned grassland if the cost of cleaning is covered by returns from the beef production. Thus we

can draw a line which is tangent to the concave efficiency set at the point R. The point Q_R represents the sum of hectares initially cultivated multiplied by the unit cost of regaining additional grassland reduced by the fixed cost. It resembles to the certainty equivalent point T in Figure 1 but it is not. Because while it is possible to re-gain the grassland for some unit cost, it is not supposed that the farmer has the opportunity to lease his land out for the same cost. Thus if the farmer has some degraded grassland which can be re-utilised for a constant unit cost, the efficient frontier is concave until the point R and it is linear to the right of this point. The market opportunity line¹ without agreements must go through the point R because we suppose that the farmer already re-gained the grassland he needed and the cost of regaining any supplementary grassland would not be covered by the stochastic returns.

If an agreement payment t is proposed to the farmer for cleaning supplementary grassland, the perceived unit cost of re-utilisation falls so that the new market line emanates from the point Q whose value is by T lower than the value of Q_R . (T is equal to the sum of initially utilised grassland multiplied by the agreement payment t . It has little practical meaning.) A farmer with the preference structure depicted in the picture would regain the grassland corresponding to the share $|AB|/|AQ|$ of the grassland initially at hand $|AQ|$. Increasing the agreement payment t to t' makes the perceived cost to fall even more, the new intercept of the market opportunity line with the y-axis is at the point Q'. As expected, the quantity of regained grassland increases after an increase in the agreement payment ($|CD|/|CQ'| > |AB|/|AQ|$). This increase is unambiguous for a concave efficiency locus and DARA preferences.

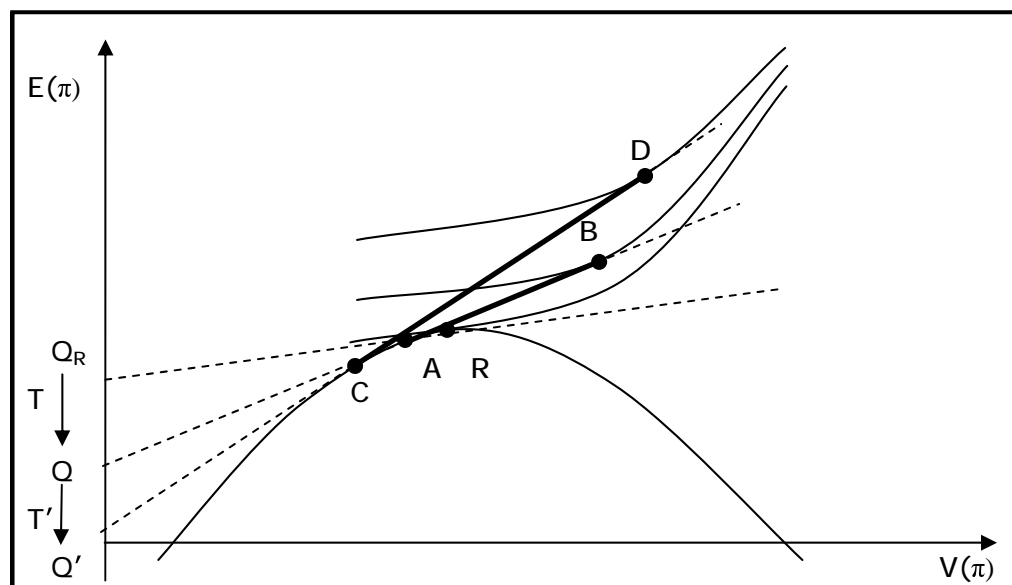


Figure 2. Tobin's separation theorem and the complementary beef and biodiversity production

The profit variability corresponding to the risky activities bundle characterised by point C is lower than at the initial point A. This implies that in cases, where an agri-environmental payment aiming at biodiversity production competing with beef production enhances the farming intensity on the parcels not subscribed under it, an agri-environmental payment aiming at biodiversity production complementary to beef production will lead to a fall of the farming intensity on parcels utilised before the agreement subscription.

¹ The line creating the linear segment will be called the market opportunity line also here in order to save a correspondence with the competing production case.

3. An illustrative application

How this concept can be applied in practice is demonstrated on a case study of beef and biodiversity production by suckler cow farms in *Monts du Cantal, Massif Central* (France). The *Monts du Cantal* is a humid volcanic region with an altitude reaching from 900 to 1300 meters where the cattle rearing plays a crucial role in the preservation of an open countryside and of the species richness of omnipresent meadows. Several zones were designated as Environmentally Sensitive Areas, ESAs, (Opérations Locales Agri-Environnementales, OLAE) in order to enhance both the complementary and the competing beef and grassland biodiversity production.

A representative of the competing beef and biodiversity production is the ESA “Tourbières du Nord Cantal” (Peatlands of the North Cantal). It is constituted around valuable peatlands where the danger of over intensification is predominant because of the fragility of these biotopes. Several agri-environmental agreements were proposed to farmers containing basically restrictions on fertilisation and on the animal density. The eligibility of parcels for a particular agreement depends on their distance from the peatland; the constraints become more severe when approaching the peatland.

The ESA “Haute Vallée du Mars” (High Valley of Mars) concerns a valley, where on the contrary the grassland biodiversity is jeopardised by abandonment or by very low intensity of agricultural activity. The beef and biodiversity production are complementary there. The agri-environmental agreements impose in this case minimal animal density requirements and demand a renovation of already degraded grasslands. A good representative is the agreement aiming at regaining heavily degraded pastures (pastures covered by more than 35 % by bushes), which asks the farmers for mechanical cleaning in the first year and for maintenance by pasture in the following years. Agreements are signed for 5 years.

3.1 Model description

Efficient frontiers can be obtained by solving the following programming model

$$\min V = \sqrt{\sum_k w_k (\pi_k - \bar{\pi})^2} \quad (1)$$

such that

$$\sum_j a_{ij} X_j \leq b_i, \quad \forall i \quad (2)$$

$$\pi_k = \sum_j c_{jk} X_j - FC, \quad \forall k \quad (3)$$

$$\bar{\pi} = \sum_k w_k * \pi_k \quad (4)$$

$$\bar{\pi} \geq \lambda \quad (5)$$

$$X_j \geq 0, \quad \forall j \quad (6)$$

$$\sum_k w_k = 1, \quad (7)$$

where X_j is the level of activity j , a_{ij} is the input requirement coefficient of activity j for input i , b_i is the quantity of input i at hand, c_{jk} is the gross margin of activity j if the state of nature k occurs, FC the fixed cost, and π_k is the profit in the state of nature k . w_k is the probability of the state k and $\bar{\pi}$ is the expected profit. The efficient frontier is obtained by minimising the standard deviation of the profit (1) by progressively increasing the minimal expected profit required by the parameter λ in (5).

In order to carry out this analysis, we applied a simplified version of the Opt’INRA Salers. Opt’INRA Salers is a linear programming model constructed on the basis of the Opt’INRA model² and adapted for the analysis of suckler cow farms breeding the Salers cow in the studied region. INRA has an experimental farm in *Marcenat*, on the *Cézallier plateau* in the Cantal region of France, which is home to a herd of suckler cows of the hardy Salers breed. It is an experimental site for the EU project FORBIOBEN³ and has reliable technical references on forage and animals at one’s service.

² See a detailed description of this model in Veysset et al. (2005).

³ FORBIOBEN: Foraging for Biodiversity and Benefits, QLK-2001-00130

Complementary data sources used for the parameterisation of the Opt'INRA Salers were: historical cases from regional farm networks (Réseaux d'Élevage Auvergne et Lozère, 2003), the opinions of experts from the Chamber of Agriculture of the Cantal and technical references obtained by INRA's proper research on the types of Salers animals and the mountain forage areas. The model was initially constructed as follows:

The objective function that the program intended to maximise was the overall gross profit margin, in other words, the yearly products (sales and premiums) less the assignable costs (breeding costs, feed, fertiliser and treatment expenses, harvest costs).⁴

Animal production determines breeding activities (different stages of the life of an animal in relation to its diet and the production goal) and sales. The central element was the Salers suckler cow. It calves on February 15, can be fertilised by a bull of the Salers or Charolais breed and may or may not be "premium-eligible". The herd was restocked with heifers from stock in the case of pure-breed farms and with the purchase of heifers of different ages for mixed-breed farms. All of the sales categories of males and females (young, old, lean, fat, premium, non-premium) encountered at this time in the area studied were represented in the model.

Animal feed was based on conserved forage (hay, bales or regrowth) in the winter and on pasture alone in the summer because the entire utilisable agricultural area (UAA) was constituted by grassland. All of the forage was produced on the farm and could be supplemented by purchased concentrate when necessary. Rations for each animal were calculated according to its weight, its needs (production, growth) and the quality of the forage dispensed, maximising the quantity of forage ingested. Each animal could choose between different types of rations but with the same nutritional value. Opt'INRA Salers arbitrates between the number, the type of animal and the types of rations provided in order to balance needs and resources.

The grassland management system is relatively complex. Different types of grasslands were defined according to the farmers' practices (early mowing + grazing, late mowing + grazing, topping + mowing + grazing, etc.). A grassland management schedule was established and the growth and grass farming season was thus divided into six periods. For the purpose of this study, we considered that all of the hay meadows received organic fertilisation corresponding to the herd maintained during winter. Each type of grassland produced a specific quantity and quality of forage for each period.

Two simplifications were applied to this model in order to make the results more transparent. First, in the original version the model accounts for the heterogeneity in parcels; distinction is made for example between areas that can be used as hay meadows and those that cannot or between fertilisable and non-fertilisable areas. This heterogeneity was removed from the model which is applied here. All the parcels are homogeneous and the model is entirely free to decide about the number of hectares managed in a particular way. The second simplification concerns the administrative framework. In the original model the pertinent CAP premiums are depicted and the model can choose whether or not to claim each premium, with the constraints that this implies. These constraints were likely to deteriorate the comparability of results obtained, with the theoretical framework exposed above, which does not account for them. We aggregated all the premiums in a single payment attributed per livestock unit. (The amount of this payment was calculated from results obtained with the original model for the CAP 2002 payment scheme.)

Uncertainty stems from the volatility of output prices. Five sets of prices were used corresponding to annual average output prices of the years 1998 – 2002. Not having at hand any more suitable estimation of subjective probabilities, the farmers accord to these prices, we assumed that any of these sets of prices can occur with the same probability, 20 %. In order to analyse the impact of different price levels and different degrees of price variability on the environmental good production, the output prices were in the model defined in the following form

$$p_{jk} = \bar{p}_j * (1 + \varepsilon_{jk} * h), \quad (8)$$

$$\text{with } \varepsilon_{jk} = \frac{p_{jk} - \bar{p}_j}{\bar{p}_j},$$

⁴ For the application in this paper, the non-assignable cost was subtracted as fixed cost from the products because for a DARA farmer also the level of the efficient frontier, not only its shape, matters.

where P_{jk} is the price of the output j in the state of nature k , \bar{P}_j is the expected value of the price of output j and ε_{jk} is the deviation from the expected price in the state k . The parameter h serves to model an increase in the price variability without impact on the price level.

The agreement representing the ESA “Tourbières”, where the aim is to reduce the intensity of farming in the neighbourhood of the peatlands, is modelled by the possibility not to utilise up to 25 ha of the total UAA, which is 100 ha, in exchange for a per hectare agreement payment (450 €/ha/year). The agreement applying to the ESA “Mars” is represented by the possibility to acquire up to 25 ha of additional grassland to the initial 100 ha. There is a unit cost attributed to the cleaning of the parcel (750 €/ha/year during 5 years) and a payment for each hectare cleaned (300 €/ha/year). The number of hectares eligible for both agreements is limited to cover only a part of the farm, and on one farm hectares eligible just for one of the two agreements can be found as they concern distinct ESAs.

3.2 Results

In this section the results of model simulations are presented in the form of efficient frontiers in an expected value – standard deviation space, the number of hectares subscribed under one or another agreement, and farming intensity expressed as the number of livestock units (LU) per hectare.

Figure 3 contains results for competing beef and biodiversity production. The efficient frontier corresponds to the concave curve. It consists of four segments, two linear ones and two concave ones. The segment N° 1 is linear and it emanates from the value of expected profit $E(\pi)$ where the standard deviation $V(\pi)$ is equal to zero. This point generally corresponds to the negative value of fixed cost and to zero agricultural activity. But in the modelled case, the farmer has the possibility to subscribe a part of his land under an agreement which remunerates him for not utilising it. So the highest expected profit attainable is equal to the negative value of fixed cost plus the number of hectares eligible for the agreement (25 ha) multiplied by the agreement payment. (This point is not depicted in the picture.)

The first segment is linear because the farmer determines once the optimal structure of his activities and then he only increases the share of land in production before the limit of a fixed factor, here only land is considered as such, is hit. This is confirmed by the shape of the dashed curve which represents the farming intensity and whose value is in the first segment constant. (The value can be read on the secondary y-axis.) The number of hectares subscribed under the agreement is denoted z and corresponds to the Z-shaped curve. Its value can be read on the principal y-axis similarly as the expected profit which is expressed in 1000 €. In the first segment, all the eligible grassland is subscribed under the agreement.

When the grassland quantity becomes a limiting factor for further increase of the expected profit, adjustments in the production structure occur in order to use the land more efficiently and to save the agri-environmental payment for as much of the eligible land as possible. This leads to a more than proportionate increase in the variability of profit when the expected profit increases. The efficient frontier becomes concave, segment N° 2. This segment is characterised by an increasing farming intensity on the utilised land, and for higher levels of expected profit by a slight fall in the number of hectares subscribed under the agreement.

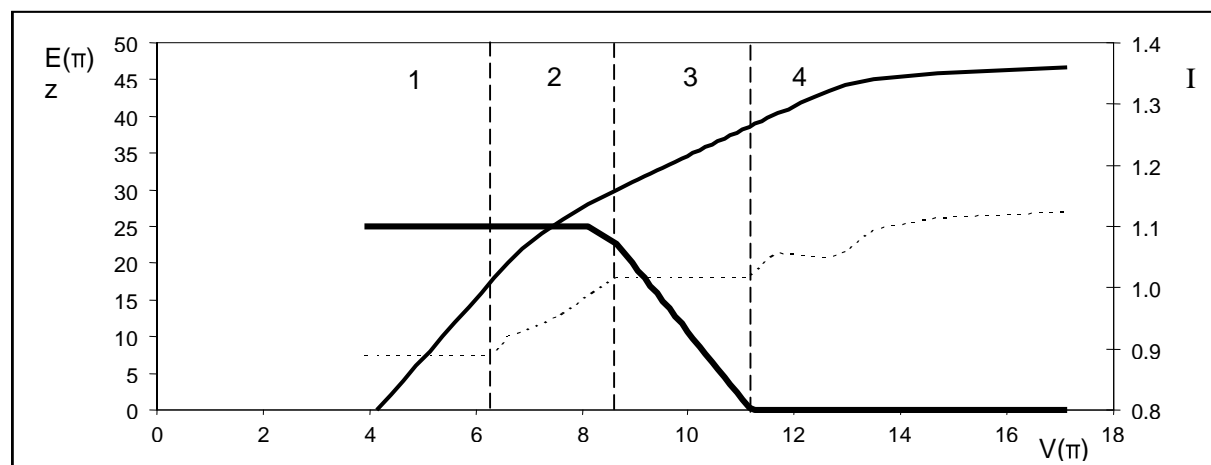


Figure 3. Portfolio optimisation with an agri-environmental agreement for competing beef and biodiversity production.

The linear segment N° 3 corresponds to a progressive reduction of the grassland subscribed under the agreement with a constant farming intensity on the non-subscribed grassland. This segment is a fragment of the market opportunity line as presented in Figure 1. Its tangent cuts the y-axis at the value equal to the total number of hectares multiplied by the agreement payment minus the fixed cost. As only a part of the grassland is considered as eligible for the agreement, not the whole market line can be integrated in the efficient frontier but only its fragment. The Tobin's separation theorem applies to this part of the generated frontier. Along the segment N° 3, the farmer holds the structure of the portfolio of risky activities constant and he optimises the overall portfolio including environmental good production by varying the proportion of grassland committed to beef and biodiversity production, respectively.

The last concave segment, N° 4, corresponds to the situation when no grassland is subscribed under the agreement. At this stage, additional expected profit can be obtained only by adjusting the farming system, which also actually happens as can be seen regarding the evolution of the farming intensity. This segment is identical to the corresponding part of an efficient frontier when no agri-environmental agreement is proposed.

The case of complementary beef and biodiversity production is depicted in Figure 4. The efficient frontier is once again composed of two linear and two concave segments but their meaning is different from the case above. The linear segment N° 1 emanates from the point where the standard deviation is equal to zero and the expected profit is equal to the negative value of fixed costs. (This point is not depicted in the picture.) The reason of the linearity is the same as in the competing beef and biodiversity case. The linear development lasts as long as there is some free non-degraded grassland. In this segment no land is subscribed under the agreement aiming at regaining the degraded grassland. (The curve representing the number of hectares subscribed under the agreement aiming at complementary beef and biodiversity production has a reverse Z shape.)

Adjustments in the farming system, which are behind the concavity of the segment N° 2, are motivated by the aim to use the non-degraded grassland as efficiently as possible before proceeding to cleaning some additional land. The farming intensity increases in this segment and only for high levels of expected profit a small area of degraded grassland is subscribed under the agreement and cleaned.

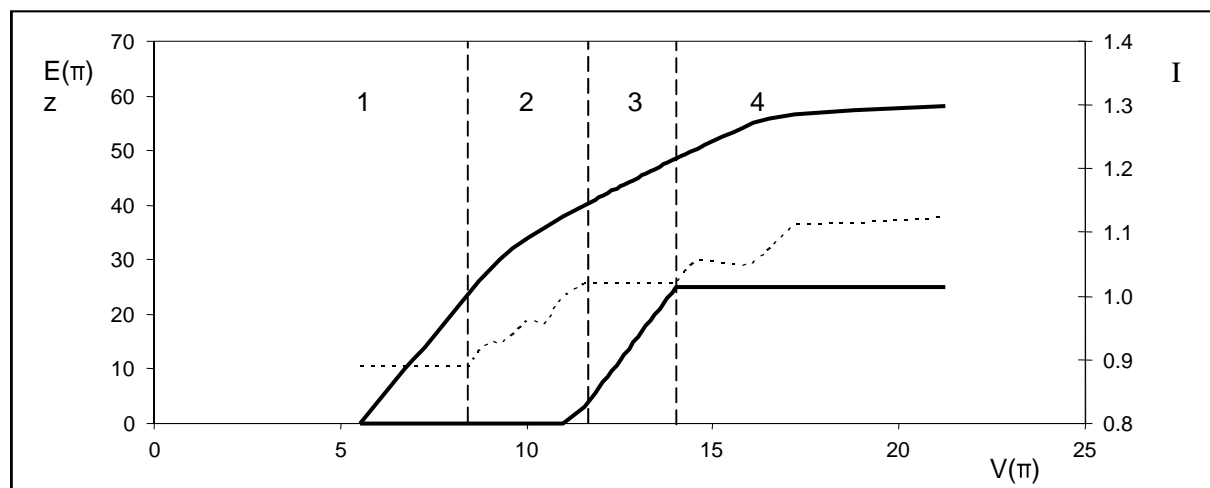


Figure 4. Portfolio optimisation with an agri-environmental agreement for complementary beef and biodiversity production.

The segment N° 3 is linear and it corresponds to a part of the market opportunity line in Figure 3. (Only “to a part” because the amount of degraded grassland is limited.) In accord with the Tobin's separation theorem, the structure of beef outputs and farming intensity are constant and the adjustment concerns just the extent of the beef and biodiversity production. The number of hectares subscribed under the agreement increases linearly. In the last segment, N° 4, all the hectares eligible are already subscribed. This segment is concave because there is no further possibility to acquire additional grassland and the expected profit can be increased only by changing the farming system.

The indifference curve map is to be added into the schemes generated by the model in order to analyse the impact of variation in policy parameters on the quantity of grassland subscribed under an agri-environmental agreement. If properly drawn, according to the assumption made – the DARA

preference structure, this map is sufficient to derive qualitative conclusions for analysed parameters. Figure 5 contains efficient frontiers generated for two different levels of agreement payments, the curve describing the amount of hectares involved under an agreement, and the indifference curves.

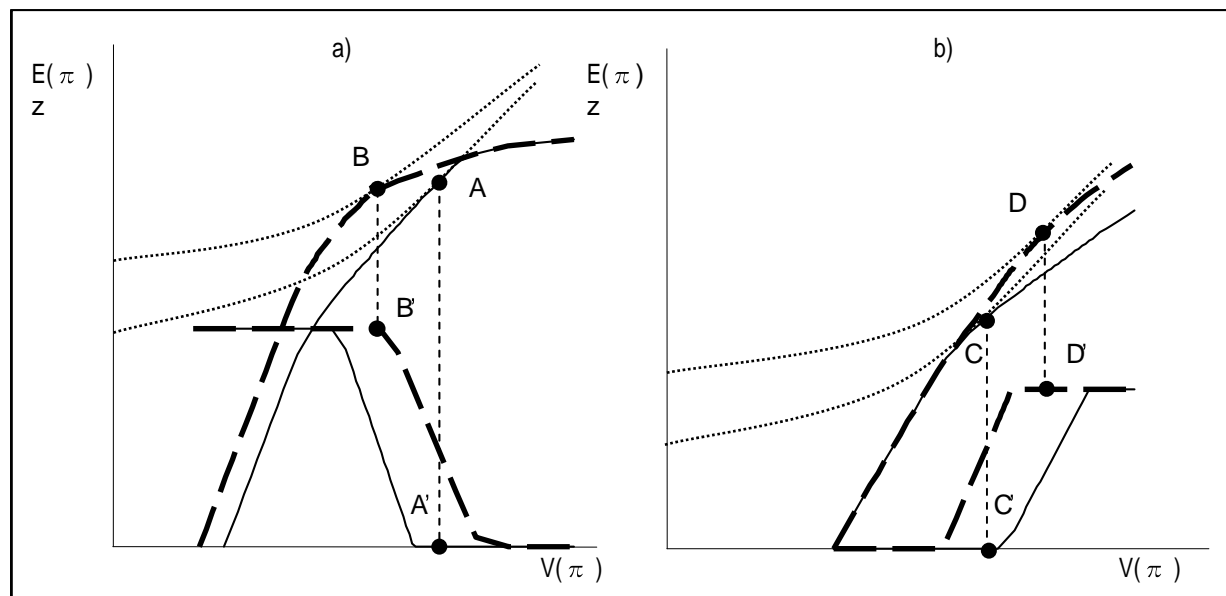


Figure 5. Effects of different levels of agri-environmental payments on a) competing and b) complementary beef and biodiversity production.

The competing production case is presented in Figure 5a. The base situation, the one exposed in detail in Figure 3, is drawn in light lines. (The farming intensity is for sake of clarity omitted here.) The tangency point between the efficient frontier and the appropriate indifference curve is the point A. The point A' on the Z-shaped curve corresponds to the point A on the efficient frontier. The quantity of biodiversity produced is zero. Increasing the agri-environmental payment, by 300 €/ha here, makes the efficient frontier flatter for high levels of profit and in the region, where some grassland is subscribed under the agreement, the new efficient frontier is situated above the original one. The tangency point between the indifference curve and the efficient frontier is now the point B with the corresponding point B' on the dashed Z-shaped curve. As expected, more hectares are subscribed under the agreement for higher levels of agri-environmental payment.

The increase of the agri-environmental payment in the case of complementary beef and biodiversity production is graphed in Figure 5b. The new efficient frontier is represented by the dashed curve. For higher levels of profit, the new efficient frontier is above the original one and its second linear segment is steeper. The initial optimum point is C. The corresponding point on the reversed Z-shaped curve is the point C', the number of hectares subscribed under the agreement is zero. After an increase of the agri-environmental payment, by 300 €/ha, the optimum shifts from the point C to the point D. The corresponding point D' on the reversed Z-shaped curve indicates that all the hectares eligible for the agreement are subscribed. Thus increasing the environmental payment promotes biodiversity production.

In section 2, we derived that increasing the agreement payment will lead to an increase (decrease) in the farming intensity if the beef and biodiversity production is competing (complementary). The simulation results confirm these propositions as can be seen in Figure 6. Figure 6a contains results in terms of farming intensity on the grassland not subscribed under the agreement, corresponding to the efficient frontiers depicted in Figure 5a. The dashed curve presents values for the increased level of the agreement payment. These values are higher or equal to the values corresponding to the initial payment level. The farming intensity values corresponding to the results in Figure 5b are reported in Figure 6b. Here, the farming intensity for an increased agreement payment is less or equal to the values under the initial payment level.

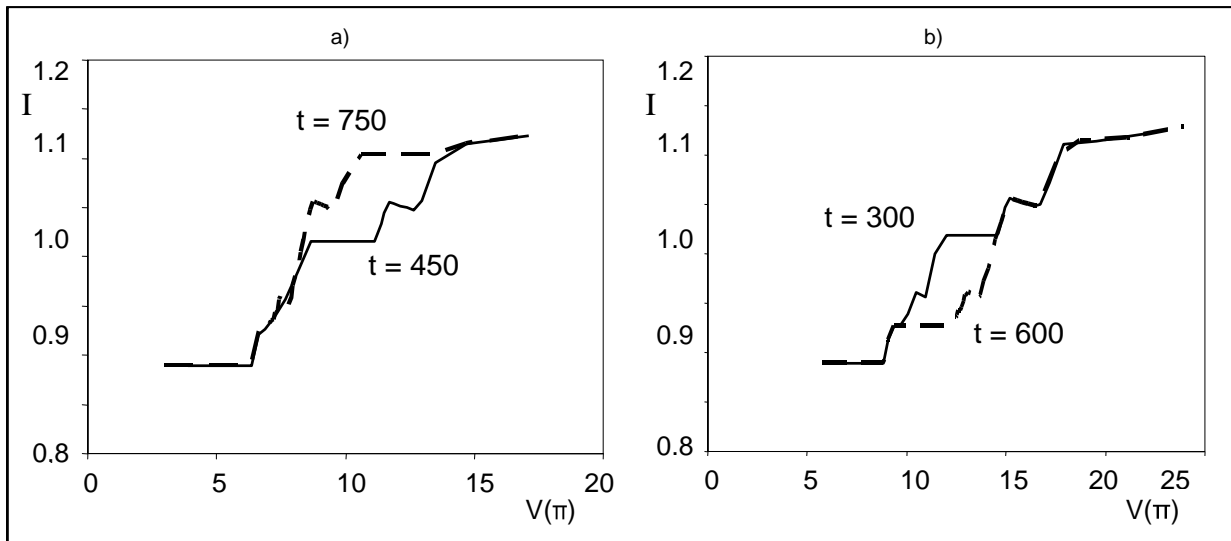


Figure 6. Effects of different levels of agri-environmental payments on farming intensity in the a) competing and b) complementary beef and biodiversity production case.

3.3 Decoupled subsidies and uncertainty

In what follows, comparative statics are derived for the parameters of special interest for the recent CAP reform analysis: level of the decoupled subsidy and of the output price variability.

Effects of the introduction of a decoupled subsidy in the form of a lump sum payment are presented in Figure 9, where a lump sum payment of 5000 € is accorded to the farmers. The lump sum payment shifts the efficient frontier upwards and the new locus is perfectly parallel to the original one. As a result, for a particular level of the variability of the expected profit, the same quantity of grassland is subscribed under the agreement for whatever value the lump sum payment takes. This is true both for the case of competing as well as complementary beef and biodiversity production. As the slope of the efficient frontier corresponding to a particular quantity of grassland under the agreement is not influenced by the lump sum payment, the lump sum payment would have no effect on the quantity of grassland put under the agreement if the farmer's preference structure were CARA (Constant Absolute Risk Aversion) because CARA indifference curves have the same slope for a particular variability for all levels of the utility. This is not the case under the DARA preference structure.

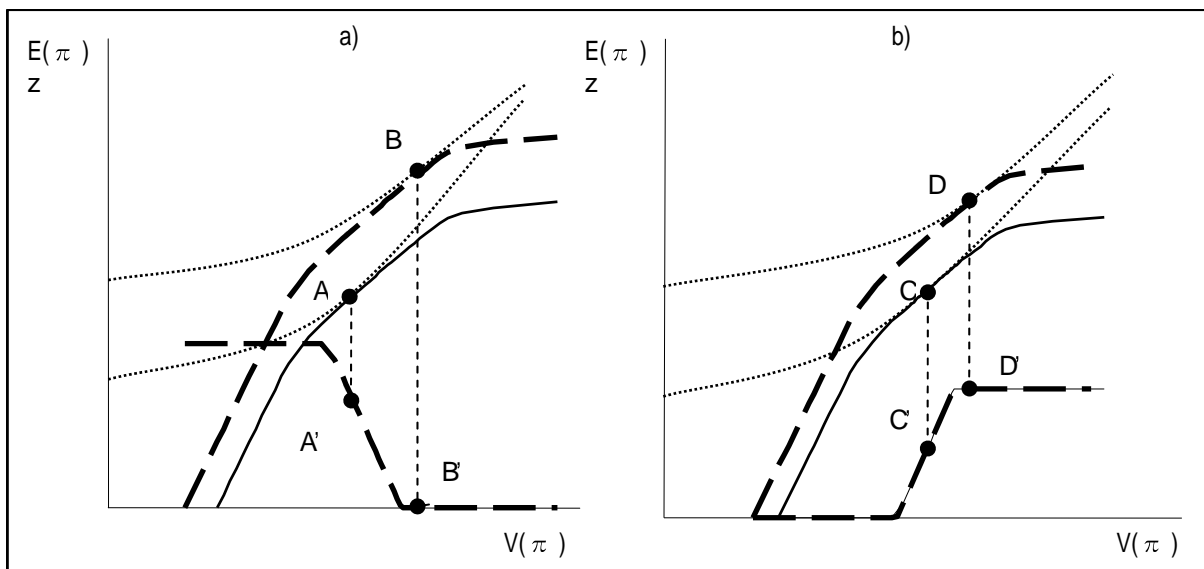


Figure 7. Effects of different levels of a decoupled subsidy on a) competing and b) complementary beef and biodiversity production.

DARA indifference curves are getting flatter when the utility increases and so their tangency point with the new efficient frontier is situated to the right of the initial one, which causes the shift from the point A to the point B in Figure 7a and from the point C to the point D in Figure 7b. As we can see, introduction or an increase of the lump sum payment is not without impact on biodiversity production by DARA farmers under uncertainty; it decreases the biodiversity production if it is competing with the beef production and increases its production if there exists a complementarity.

For the analysis of a change in the level of uncertainty, we consider an increase of the value of the parameter h , from 2 to 5. In the case of competition between beef and biodiversity production, the indifference curves are nearly horizontal for low levels of variability and they become tangent to the efficient frontier in its upper part where no grassland is under the agreement, the point A' in Figure 8a. After an increase in the output price variability, the farmer finds it optimal to produce some positive level of biodiversity, the point B'. He has two reasons to do so: first, the highly variable income from agricultural production is not excessively attractive for him and so he is more inclined to give up a portion of it, second, the stable income he can receive for the biodiversity production is a welcome possibility to stabilise the profit.

When the beef and biodiversity production is complementary, Figure 8b, the increase in the level of uncertainty is harmful for biodiversity production because the cost of regaining the abandoned grassland is never completely covered by the agreement payment and it should be partially compensated by supplementary gains from beef production. An increase in the output price variability makes these supplementary gains less attractive and thus not sufficient to motivate the farmer to clean the same number of hectares as before the increase in variability; the amount of grassland subscribed under the agreement falls from the initial level corresponding to the point C' to the new level corresponding to the point D'.

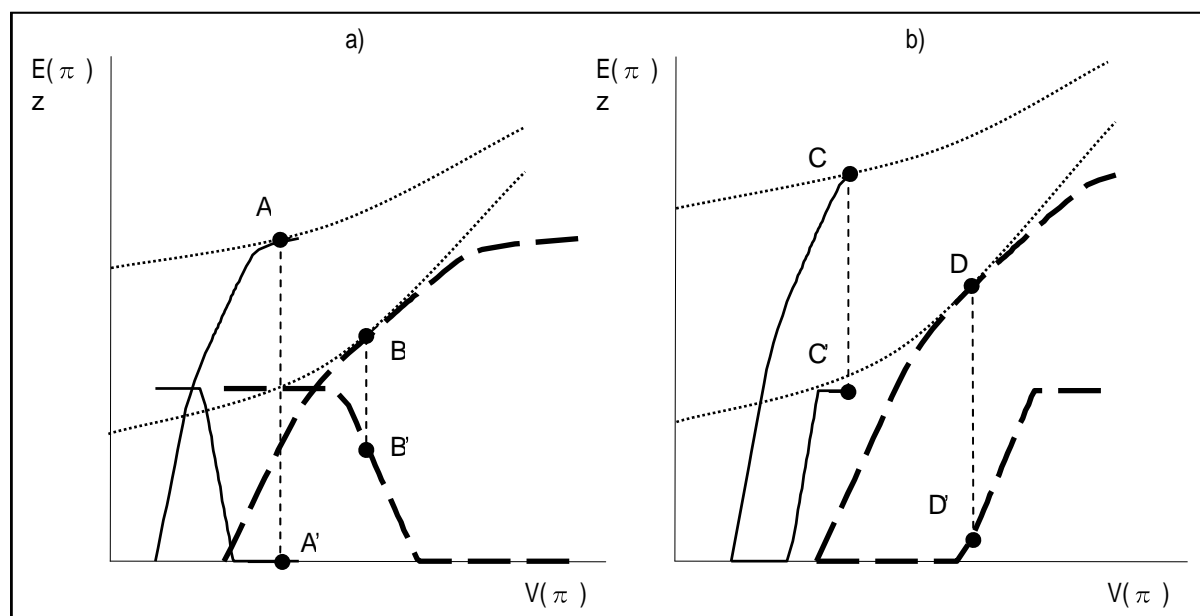


Figure 8. Effects of different levels of output price variability on a) competing and b) complementary beef and biodiversity production.

4. Discussion and conclusions

An analytical framework was proposed which enables to analyse the willingness of a DARA risk averse farmer to subscribe an agri-environmental agreement when facing uncertainty in output prices. In this framework, the environmental good production is considered as a riskless activity. Both competing as well as complementary beef and biodiversity production is analysed applying mathematical programming farm level models of a representative suckler cow farm in the *Monts du Cantal*. However, the agri-environmental agreements modelled represent just the extreme cases where in the competing case some grassland should be completely diverted from beef production and in the complementary one some completely abandoned grassland is to be reutilised. In reality, many agreements demand only lowering of the farming intensity or cleaning of only partially degraded

pastures. As we dealt with the extreme cases in order to make more visible the principles of the proposed framework, the obtained results remain qualitative.

We demonstrated that parcels not subscribed under an agreement aiming at lowering the farming intensity will be managed more intensively after an increase of the agreement payment. As such agri-environmental agreements often request “low” farming intensity and not “lowering” of the farming intensity, the farmer usually subscribes parcels where the intensity is already sufficiently low for whatever reason, e.g. pure land quality, and not the others. While the environmental effect of such an agreement is zero if the farmer is risk neutral, the environmental effect is negative if the farmer is risk averse. This result favours whole farm agri-environmental programs which require that also the grassland not subscribed under specific agreements should be managed in an environment friendly way.

Decoupled payments linked to properly designed cross-compliance conditions could provide this whole farm framework for more specific local agri-environmental measures. But they should be used carefully because their impact on the farmers’ willingness to adopt supplementary agri-environmental measures will depend on the type of jointness underlying the agricultural commodities production and the production of particular environmental goods, and on the change in output price variability which is likely to accompany the decoupling process. Depending on the evolution of output price variability, introduction of a completely decoupled subsidy may produce 3 different outcomes in terms of environmental good production: 1) if the introduction of decoupled subsidies will not be accompanied by an increase in the price variability, production of environmental goods competing with agricultural commodities is likely to fall but the farmer will be motivated to subscribe agreements concerning environmental goods complementary to agricultural commodities, 2) if the introduction of decoupled subsidies will be accompanied by a proportionate increase in output price variability, the willingness of farmers to adopt specific agreements will not change 3) if the increase in the price variability will be more than proportionate, the farmer will be more willing to subscribe agreements aiming at environmental good production competing with agricultural good production and his interest in environmental good production complementary to agricultural good production will decrease,.

All these results rely on the assumption that environmental good production represents riskless activity for the farmer and further developments of the model are possible in the sense of relaxation of this hypothesis. Although we can consider the revenue as guaranteed, farmer may perceive as uncertain his effective cost of compliance with the agreements, especially if he has no experience with restrictions or tasks involved in an agreement. In the literature, this cost is usually considered as known by the farmer. Some empirical studies on this issue would be of interest.

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