Bargaining on Ecological Main Structures for Natural Pest Control:

Modelling Land Use Regulations as Common Property Management

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Abstract

In this paper we argue that the loss of bio-diversity should be of concern for farmers, though it seems to be of little or no concern to them at the moment. As diversity is a component of nature that controls the growth of pests, a loss of bio-diversity means increased exposure to pests, danger of crop failures and, in the long run, lower average yields and profits. So far farmers buy costly pesticides for compensating the reduction of bio-diversity. We argue that institutional problems are the reason why farmers are not concerned with bio-diversity, and show that under pure private property rights farmers have interest in pesticides and not in bio-diversity as a measure of crop protect because they have perhaps to devote land to the natural eco-system. In contrast, public policy which is assumed to make bio-diversity improvements, and this policy may pay off. Note, the prerequisite for improved in biodiversity through the establishment of an ecological main structure (EMS), may reveres this trend. We show that joint efforts in a community of farmers can result in building up an adequate size of nature elements in landscapes (an EMS) for maintaining the bio-diversity. These nature elements shall allow, in parts, a more sustainable performance of pest control than chemical control. The public control instrument is the EMS size. For this, in the paper, we extend the institution economics model of Rausser and Zusman (1992) on productive governments to bio-diversity.

Keywords: Common property management, institution, crop risk and bio-diversity; JEL: Q28

1 Introduction

The overall loss of species in farming areas through modernization, intensification and mechanization of agriculture, increased application of chemical substances, and, in particular through a minimising of nature elements such as hedgerows, small forest and wetlands, has attracted the attention of ecologists. Especially in the past nature elements in an ecological main structure, EMS, have strongly supported bio-diversity in the countryside as well as maintained an equilibrium between pest pressure and agricultural productivity. Nowadays, in many regions of the world we see a retreat of nature or nature elements in cultural landscapes; though general deliberations tell us that we need nature (as nature services). In farm lands, nature services (FAO-MA, 2004) such as pest control, water purification, and soil fertility, are usually provided by nature elements in these landscapes. These elements can coexist with farm land only by diminishing productive land and seemingly lowering profits.

Ecologists tell us that the observable great loss of nature elements in rural landscapes, and hence the loss of biodiversity, should not only be a concern of the public, but also of the farmers as their interest also maybe harmed. Ecologists as a lobby group want multifunctional agriculture (Cahill, 2001) and urge governments to take measures to preserve bio-diversity, in general, and especially nature elements in cultural landscapes. Opposing multifunctionality, farmers react to public conservation concerns by arguing requests for increased bio-diversity and nature elements in their fields will reduce their competitiveness and income. Farmers think that they can live with reduced bio-diversity quite well, because the previous function of bio-diversity in farming systems, essentially as a medium of pest control, has been taken over by chemical inputs. And, as long as farmers produce enough as well as high quality food, the public should not be concerned. In contrast, ecologists warn of long-term negative impacts of pesticides and prefer “natural pest control”; they assume that a further decline of cultural landscapes threatens multi-functionality and they challenge the sustainability of modern

farming systems. This seems to be a conflict that can only be politically solved. Others see the conflict as an institutional problem of property rights (Hodge, 1988) and favour private property; but a deeper insight into institutional problems may be involved in the debate on natural pest control. The question is: What happens if farmers work together? In this context a local government, as a public manager who "prevents" pest by a diverse nature, may play a role (see Rausser, 1992, on predatory versus productive government). Accordingly, we argue that institutional problems have been overlooked and both, farmers and ecologists, may benefit from natural elements and multifunctionality.

It is the primary objective of the paper to develop a model which helps to understand why farmers are reluctant to support bio-diversity projects that are based on EMSs. To show the potential for common property management fostering bio-diversity and controlling pest biologically, we explain how to depict optimal public regulations within a framework of public bargaining. In this case public bargaining is about field margin provision of farmers. The secondary objective is to show that a biased manager rather than a benevolent dictator can be perceived and that a biased though effective regulation results. The paper is structured as follows: Section 2 gives an outline of the idea. It provides arguments for developing a model that caters for public choices on measures against production risk using a landscape approach (EMS). Section 3 presents a framework for modelling an EMS in conjunction with farm behaviour. Section 4 discusses the tragedy of the commons and a benevolent dictator, and section 5 offers the result for group management by choosing a politically corrupt but powerful manager. Herby nature is a common property reducing costs and we assign nature service a value.

2 Outline of the approach

The presented model uses the political economy approach on bargaining for public goods of Rausser and Zusmann (1992) to derive an objective function of a farmer community in nature

conservation. The objective function will contain an EMS as a jointly producible, communally owned and managed resource. Biodiversity is retained through preserving nature elements in an EMS embedded in farming (McNeely and Scherr, 2002). Though losing profits by cultivating less land, farmers concede land to a community because they gain indirectly from a better environment. The aim is attaining less pest pressure in farm lands through a more diverse biota by allocating land for nature. Farm land is private, but a "nature manager" has the right to impose statutory regulations on some land. Regulations imposed by a manager for the public good 'nature' are obeyed by farmers. Here, the basis for the common property management is an EMS to which farmers voluntarily contribute. Land is used for hedges, stone walls, ditches, wet lands, etc..

The production and cost functions as well as the decisions of farmers are oriented towards bio-diversity giving higher private profits. The rational is to use the EMS as a basis to conduct a community-wise and private evaluation of nature. Since bio-diversity in the form of multiple species occurrence shall reduce risk of crop failures, the public manager cares about nature and farmers. Caring requires a communal objective function containing nature. In modelling, for technical reasons, nature is represented by a bio-diversity index, which counts in management and enters the objective function. Then communally produced bio-diversity becomes an element in the production function of farmers, as it reduces the risk of crop failure. As will be shown by duality theory, bio-diversity appears in a cost function of minimizing risk. We assume substitution between both, purchased chemical inputs and nature. Bio-diversity is then an effective risk reducing natural device through public management.

A reduction of financial costs in plant protection shall be achieved through a political economy approach of managing the commons. Note that costs enter the objective functions of farmers and the community. The model shows how aggregation of private objectives can be perceived. On behalf of a community, a manager of the natural environment maximises his

net benefits from additional nature elements and minimises costs from economic risks of crop failures. As opposed to an unorganised community, which degrades the environment, the managed community shall be better off. But the benefit is not the benefit of a benevolent dictator; it is skewed through a political process of rent seeking.

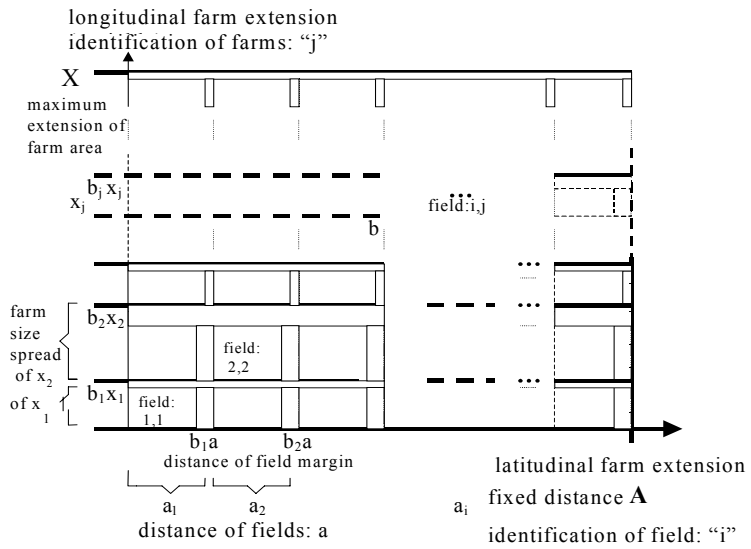
However, for farmers costs and benefits count differently. Their indirect *benefits* are reduced financial costs of risk, expressed as reduced purchases of equivalent chemical substances to combat pests. These pests occur if natural predators are not available due to lack of habitats. Direct c*osts* are created by waivers of full utilisation of land, such as buffer strips or field margins used for the EMS. Furthermore, farmers must use "resources" for rent seeking (Rausser and Zusman, 1992), hence, interactions must be researched. Since nature "production" relationships are essentially confronted with potential improvements, farmers are normally sceptical whether a risk reduction can really be achieved. In contrast, pesticides mostly offer immediate cures of pests and guarantee high yields. Apparently, there is a trade off between a will to save pesticides and the uncertainty of getting the delivery. The model reconsiders the problem of uncertainty by putting certain probabilities on natural processes and modelling decision making as a stochastic problem of crop failure and risk. It uses standard approaches of cost functions, techniques to cater for risk, and strategies of farmers to assure against risk.

3 Modelling of farm behaviour, risk and Ecological Main Structures (EMS)

3.1 A framework for farmers' participation in bio-diversity/EMS and interest functions

Our basic analytical framework for the description of farmers' participation is an EMS (Oskam and Slangen, 1998). For diversity provision it focuses on spatial allocation of land by farms (Wossink, et al, 1998). This spatial frame will enable us to (re)formulate Rausser and Zusman's (1992) initially time oriented model as a spatial model. A stylized framework is necessary to get dimensions of space and farms in one dimension of decision making, given

limited space. It also provides a tool for empirical application, since field margins and the size of the EMS are displayed. Figure 1, below, depicts the idea of a plot oriented agriculture including field margins.



The latitudinal axis with equal distances (a_1, a_2 ,..., a_i, ... to a_n) shows the horizontal stretch of a farming community at equal distances of fields (conceived in a polder or settler frame-work of land distribution).

Figure1: Spatial Allocation and Ecological Main Structure Farm sizes differ on the longi-tudinal-axis allowing farms to have different sizes according to distances (x_1, x_2, ...x_j,... x_m). This framing of farms enables us to depict land allocation and the implementation of the EMS in the mode of field margins. From definition

$$l^*_{ij} = a_{ij}\ x_j \qquad (1)$$

we derive the size l^*_{ij} of a field. Next, the area contributed to the ecological main structure f^*_{ij}, which can be identified on field "i" of a farm "j", can be depicted as percentage of the size of the field. Using a Taylor series expansion for a rectangular field "$a_{i*}x_j$" multiplied by a percentage b_j, we receive an approximated f_{ij} as size of field margin, applied, depending on b_j

$$f_{ij}= a_{i,0}\ b_j{*}x_j + x_{j,0}\ a_i{*}b_j - a_i\ b_j * x_j\ b_j \cong 2\ x_j\ a_i * b_j \qquad (2)$$

where: $0 \le b_j \le 0.2$ and $a_i\ b^*_j * x'_j\ b^*_j \cong 0$

Accordingly, the remaining area that is not subject to field margins is defined as:

$$l_{ij} = (1\text{-}b_j)\ l^*_{ij} = (1\text{-}b_j)2\ x_j\ A/n \qquad (3)$$

In this formula, the part of the latitudinal-axis, i.e. the distance of the field "a_i", is already me-asured by the length of a farm "A" divided by the number "n" of fields (equal length of field

"a" and half distance of x). The advantage is an equivalent expression of a constraint imposed by an EMS “B” by the “length” of a farm (Rausser and Zusman, 1992: time frame becomes a spatial frame and “B” expressed in field margins). For instance, if 300 hectares have to be obtained from 1000 farms of average size of 10 ha, each farm has to provide a size of 0.3 ha:

$$B \le \sum_i \sum_j a_i x_j b_j \; ; \text{ and since } A = \sum_i a_i \text{ by assumption: } B \le \sum_j A x_j b_j \Leftrightarrow A \le \frac{B}{\sum_j x_j b_j} \qquad (4)$$

This spatial presentation helps to specify the individual use of agricultural farm land, including the provision of field margins b_j, in terms of the overall constraint imposed on farmers.

$$l_{ij} = (1- b_j)\, l^*_{ij} = (1-b_j)\, x_j\, A/n = (1-b_j)\, x_j \frac{B}{n\left[\sum_j x_j b_j\right]} \qquad (5)$$

Having specified the individual farm land as part of a risk reducing EMS and knowing ecological impacts of the EMS on crop risk, we can proceed to model individual farm behaviour.

3.2 Farmers' behaviour in field margin provision for an Ecological Main Structure

This section presents a mathematical expression of four aspects of farm behaviour. They are: 1. A representation of risk and decision-making, which shall enable us, most directly, to include nature and the EMS into cost functions; 2. A possible voluntary provision of field margins by farmers for an EMS, which enables us to reduce risk, has to be discussed formally. This will be done on the basis of a farm behaviour that corresponds to the relevant micro-economic theory of farmers; 3. A depiction of an ordinary profit maximising, which shows farmers’ limited incentives to provide field margins (tragedy of the commons: Rausser and Zusman, 1992). (Anyhow, the allocation of field margins towards an EMS has to be seen in conjunction with obtainable bio-diversity and the use of agricultural land for profits (Wossink et al. 1998).); and 4. A positive effects from ecology which reduces costs due to higher biological activity, i.e. effects from the EMS. Hereby, the EMS is managed as public goods.

3.2.1 Risk and Costs

We propose to use two steps to reduce complexity and minimise on notation in stochastic affairs. In a first step we assume that a farmer faces two distinct situations to which he attributes probabilities: y_g stands for good and y_b for bad yields. In a second step, we introduce ρ, which stands for the probability of good yields and (1-ρ) for disaster, respectively. This means, decision, risk and actual profits are split in two sequential periods. First, farmers with a probability of ρ will obtain a gross margin p^c_j and have cost C^c. Gross margins and costs are favourable in case of prevalence of high bio-diversity associated with the EMS, and there is no need for additional measures of pest control. However this depends on the probability ρ. Average costs are lower than without EMS because pesticide use is low. However, with a counter probability (1-ρ) farmers detect pest on their field (for instance insects or fungi) and either will have lower yields or use additional chemical inputs increasing costs. In the second period, anyhow, we can assume that a disaster occurs with a probability of (1-ρ) (as said, the good situation where pest control, biological or chemical, helps is ρ). Note a disaster (crop failure with a certain probability) can occur even if an EMS exists or pesticides are used, respectively. Disaster applies also to preventive pesticide use, the alternative to the EMS, perhaps on a lower probability but at higher costs. Strategically expressed, farmers who will join a community have, as a reference, a situation where profits from non-joining a community are given as additional pesticide costs and good yields. Profit considerations of farmers and corresponding decision making are focused on incremental profits from joining a community. These complex issues are modelled assuming a probabilistic decision where the two probabilities are interlaced. Alternative uses of pesticides prevail; i.e. to go for a strategy of natural control or to apply a strategy of chemical control. We start with an expected difference

$$\Delta E[\widetilde{\Pi}_{j,A}] = E[\widetilde{\Pi}^c_{j,A}] - E[\widetilde{\Pi}^p_j] \qquad (6)$$

of profits as prime criteria for improvement and use a probabilistic approach of yields, where

$$E[\tilde{\Pi}^{c}_{j,A}] = \rho_l (1+\Theta)\Pi^{s,c}_{j,A} + (1-\rho_l)(1-\Theta)\Pi^{n,c}_{j,A} \quad (6')$$

as well as consider the second term as a calculated reference at given probabilities

$$E[\tilde{\Pi}^{p}_{j}] = (1-\rho_p)\Pi^{n,p}_{j} + \rho_p \Pi^{s,p}_{j} \quad (6'')$$

where:

$E[\Pi_{j,A}]$ = expected profit gain on farm i (the reference of the fix profit has been dropped) composed of

$\Pi^{s,c}_{j,A}$ = successful profits with EMS and community, higher probability of good yields due to good nature

$\Pi^{n,c}_{j,A}$ = profits are diminished due to pest infection though an EMS exists and no use of pesticides

$\Pi^{n.p}_{j,A}$ = low profits though a chemical pest control has been conducted and expenditures for pesticides

$\Pi^{s,p}_{j,A}$ = profits with no EMS put pesticide application and higher yields due to chemical pest control

ρ_l = probability of farmers with no pesticide use modified under the prevalence of the EMS

Θ = change in the probability of farmers to face pest, being altered by the size of the EMS as index

ρ_p = probability indicating the risk of farmers after application of pesticides or prevalence of the EMS

For simplicity, further we sort for and focus on elements that contain the impact of the change in probability. Distinct profits and strategies have to be specified, whereas we focus on profits "with" and profits "without" a community oriented EMS. Moreover, we assume a linear shift in the supply function and a quadratic cost function (Chambers, 1988); at least we do it later to get decisions. The major thing to be noticed concerns the cost modelling of EMS. In this respect, we assume that farmers see community oriented risk reduction by an EMS as a yield changing function. Yields are associated with a changed probability $\rho(1+\Theta)$ due to an index Θ (explained later). As well, if the preferable situation of having good yields (low exposure to pests) is not occurring, farmers will buy pesticides. With the probability $(1-\rho)(1-\Theta)$ a threshold is exceeded where farmers have to apply pesticides which reduce their gross margins. Finally, if a disaster occurs, in a bad situation, after decision, costs are forgone and revenues are low.

$$\Delta\bar{\Pi}_{j,A} = \sum_i [p_j y_{g,i} \rho_i (1+\Theta) l_{ij} - C^{c}_{ij}(l_{ij}\rho_i(1+\Theta), r_j)] + \sum_i [p^{*}_j y_{d,i}(1-\rho_i)(1-\Theta) l_{ij} - C^{c}_{ij}(l^{*}_{ij}(1-\rho_i)(1-\Theta), r_j)] - E[\tilde{\Pi}^{p}_{i}] \quad (6a)$$

(+) (-) (+) (-)

where additionally :

$p_i y_{j,i}$ = adjusted gross margins per hectare, including yields, (profit⇑) including y yields

l_{ij} = remaining area of the field i on farm j, area cropped, (profit⇑)

$C^c(.)$ = cost function on quantity of q_{ij} at field l_{ij} with the yield $y=q_{ij}/l_{ij}$, (cost⇑=>profit⇓) if the EMS exists

r_j = costs of inputs, farm specific, especially pesticides, etc. (cost⇑=>profit⇓)

r'_j = costs of additional input after detection of pest problems, farm specific, especially pesticides (profit⇓)

This specification of risk includes varying cost functions. These functions must be given ex-ante. Financial costs are apparently lower when no pesticides are applied . Alternatives are expected costs: From our given specification of risk, as a discrete representation of yield fluctuations, alternatives of choice and opportunity costs emerge associated with different regimes and probabilities. Note, we can subtract equal terms, but must assume risk neutral behaviour.

$$\Delta\overline{\Pi}_{j,A} = \sum_i [p_j \rho l_{ij} - C^c_{ij}(l_{ij}\rho\Theta, r_j) - C^c_{ij}(l^*_{ij}(1-\rho_i)(1-\Theta), r_j) - (1-\Theta)\rho r'_j l + (1-\rho)(1-\Theta)p'_j l - c'_j] \qquad (6b)$$

Presentation (6b) and profit notation can be further simplified taking additional costs and revenues as opportunity costs into account and integrating them in perceived new cost function

$$\Delta\overline{\Pi}_{j,A} = \sum_i [p_j \rho l_{ij} - C_{ij}(l_{ij}\rho\Theta, r_j)] : C_{ij}(l_{ij}\rho\Theta, r_j)] = C^c_{ij}(l_{ij}\rho\Theta, r_j)] + C^c_{ij}(l^*_{ij}(1-\rho_i)(1-\Theta), r_j) - (1-\Theta)\rho r'_j l + (1-\rho)(1-\Theta)p'_j l \quad (6c)$$

3.2.2 Field margins and balancing private cost benefits

In a second step we add the positive indirect effect of a crop insurance (average better profits by less expenditure for pesticides), which has been discussed above as difference in expected profits, and the direct negative impact of land allocation on profits (less profits due to field margins as land reallocation) which will be discussed. In equation (6d), we introduce as policy measure a land share (%) to be devoted to an EMS, "b_j", and farmers balance effects.

$$\Pi_{j,A} = \Pi^l_{j,A}(..., b_j) + \Delta E[\tilde{\Pi}^r_{j,A}] \qquad (6d)$$

From now on we must distinguish between a farm margin, b_j, and the overall size of the EMS, B. For a farm we state a small b_j, though a positive impact of land devoted to field margin $\theta_j b_j$ in costs exist; the collective impact Θ is explained later. For notice, farmer behaviour in field margin provision is written as constrained optimisation (Chambers, 1988) and broadly forms:

$$\Pi_{j,A} = \sum_i [p_j l_{ij}(1-b_j) - C^c_{ij}(l_{ij}(1-b_j), \rho\theta_j b_j, \rho\Theta, r_j)] \qquad (6d')$$

(+) (-) (-) (+) (+) (+) (-)

where: increase: "⇑" and decrease "⇓" :

b_j = field margin as percent of field size (profit⇓)

$C^c_{ij}(\ldots)$ = corrected cost function (see above) including choices according to risk variation through the EMS

Then we split horizontal and vertical components of the size of a plot as explained previously. In that case of a regulator's influence on field margins, as a %: b_j, profits are adjusted to

$$\Pi_{j,A}=\sum_i [p_j x_j^* a_i (1-b_j) - C(x_j^* a_i (1-b_j), \theta_j b_j, \Theta, r_j)] \quad \text{with constant latitude a: } x^*_j = a\, x_j \qquad (6e)$$

Now, assuming linear homogeneity in land with respect to the cost function and equal distances of fields on the horizontal axis, Σa=A, a sum of profits from fields "i" can be rewritten as:

$$\Pi_{j,A} = A[p_j x_j^* (1-b_j) - C(x_j^* (1-b_j), \theta_j b_j, \Theta, r_j)] \qquad (6f)$$

In the given context, this is a most simple representation of profits as land allocation, as gross margins per hectare, as input costs of pesticides, and as strategic variables of risk. It also enables a treatment of public management. But, first, no public management serves as reference.

4 Tragedy of the commons in public risk management for EMS

The major argument for a positive relationship between public management of risk reduction by an EMS and field margins is depicted in relationship (7a). A change in risk of crop failure shall be linear regressible on sizes of the EMS. Note that the sizes of effects are individualised in order to care for special impact and interest of farmers. We state a constant and linear part:

$$\Theta = \Theta_{0j} - \Theta_{1j} B \qquad (7a)$$

As a further explanation: Function (7a) can be considered a reduced form of a sequential functional relationship between a risk of crop failure and bio-diversity on the one hand and bio-diversity and construction of EMS on the other hand. A diversity index D serves as measure.

$$\Theta = \Theta^{**}_{0j} - \Theta^{**}_{1j} D \text{ and } D = \Theta^{*}_{0j} - \Theta^{*}_{1j} B \Leftrightarrow \Theta = \Theta^{**}_{0j} - \Theta^{**}_{1j}[\Theta^{*}_{0j} - \Theta^{*}_{1j} B] = \Theta^{**}_{0j} - \Theta^{**}_{1j}\Theta^{*}_{0j} + \Theta^{**}_{1j}\Theta^{*}_{1j} B] \qquad (7b)$$

Admittedly, this is only a crude representation and a more elaborated scheme is perceivable. But, it suffices to explain the core arguments. Any complex representation of bio-diversity

would require a more detailed argument on the management side. Introducing the ecological constraint "B", derived from the corresponding A of farm length (see equation 4 and 5), gives profits on an individual level expressed as dependent on individual allocation "b_j" of field margins *and* communal achievement (requirement) risk depend on "B" for farm j:

$$\Pi_{j,A} = \frac{B[p_j x_j^*(1-b_j) - C(x_j^*(1-b_j), \theta_j b_j, \Theta_{0j} - \Theta_{1j} B, r)]}{\sum_j x_j^* b_j} \qquad (6')$$

For interpretation: A community of small farmers may decide on B, but only, because the pressure on all of them prompts the allocation of field margins. The question remains: Will individual optimisation behaviour go for the b_j's recognising the positive effects on Θ? Nothing has been said on voluntary provision of field margins for the EMS, so far, and the benefits to individual farmers. As a public good the ecological main structure "B", i.e. the empirically measurable equivalent of nature provision by the *community of all farmers*, is only of potential interest; it may not appear due to common property problems. To sketch the argument, we look at the optimisation towards b_j in (7) by setting first derivatives equal 0:

$$\frac{\partial \Pi_{j,A}}{\partial b_j} = \frac{-B[p_j x_j^* + C'(x_j^*(1-b_j), \theta_j b_j, \Theta_{0j} - \Theta_{1j} B, r)]}{\sum_j x_j^* b_j} + \frac{B[p_j x_j^*(1-b_j) - C(x_j^*(1-b_j), \theta_j b_j, \Theta_{0j} - \Theta_{1j} B, r)] x_j^*}{-[\sum_j x_j^* b_j]^2} = 0 \qquad (8a)$$

$$\Leftrightarrow \frac{\partial \Pi_{j,A}}{\partial b_j} = [p_j x_j^* - C'(x_j^*(1-b_j), \theta_j b_j, \Theta_{0j} - \Theta_{1j} B, r)] - \frac{\Pi_{j,A} x_j^*}{B} = 0 \qquad (8b)$$

Equation (8b) consists of two parts. The first part [..] shows how the determination of field margin size is dependent on *private* marginal costs C′(.). The second part can be interpreted as the share of farm j's profit in the provision of the *public EMS*. There is a private benefit in terms of reduced public purchase of pesticides, though it is small. Two cases can be distinguished. 1. For the first part, we assume that on an individual farm the impact on cost reduction of an own field margin b_j is small (while impacts of B may be high) and, for the second part, we assume, that the profit share is also small. If individual shares can be neglected, narrowly rational farmers will not provide the envisaged EMS. The arguments are not new (arguments

follow Rausser and Zusman, 1992): Since the impact of the EMS as a public good can be neglected, i.e. a limited size of B (lim B $\rightarrow$0) is perceived, it is a dominant strategy not to co-operate; the tragedy of the commons result. 2. Farmers will focus on the first part [...] (maybe field margins already make a strong contribution), but no political pressure exists; then they will contribute, albeit limitedly. However, the size and intensity of farming matters (Figure 2). Farmers will contribute differently, but at a very low level. Note, the willingness to contribute, in the case of a "tragedy of the commons" (equation 8), is independent of the level of "B". A divergence between social and private (tragedy) marginal willingness to contribute to a crop risk reducing EMS prevails (a Nash equilibrium), though potentially there is a benefit.

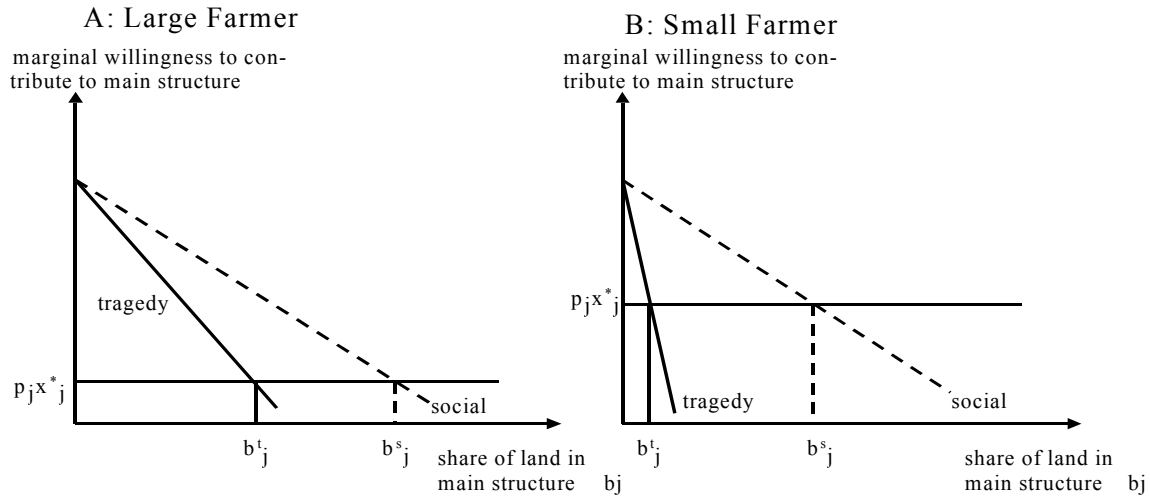


Figure 2: Farmers' individual willingness to contribute

There is scope for institutional change. The question is: How can we establish a social objective function by a political bargaining process that avoids the tragedy, if applied by a common property manager. Only then expenditures for pesticides to combat crop risk will diminish.

5 Bargain Equilibrium for public risk management

5.1 Bargaining Equilibrium

Our model of bargaining centres around Harsanyi's (1963) multiple agent model. In that model a bargaining process can be ultimately modelled as a specific functional form, such as:

$$L = [\prod_{j} (I_j - I_j^0)](I_m - I_m^0) \qquad (15a)$$

An interior solution of the bargaining process itself, as derived similar to the one prescribed by Rausser and Zusman (1992), prevails. Note the solution is also similar to a weighted objective function (15b). In that function individual weights correspond to the power of a farmer in a bargain with the manager. But as Zusman (1976) has shown, bargaining solutions are not the same as policy preference functions. Instead, the author states that the weights reflect the analytic properties of two aspects, the "production function" aspect and the "resources devotion" aspect, in bargaining (bribing). Following these arguments and referring to the proves the author (Zusman, 1976), a treatable version of equation (15a) is given in (15b). Furthermore, (15b) reveals an over-proportionality in costs of managers as the EMS size increases

$$W = \sum_{j} [1 + w_j][\frac{B[p_j x_j^*(1-b_j) - C(x_j^*(1-b_j), \theta_j b_j, \Theta_{0j} - \Theta_{1j} B, r)]}{\sum_{j} x_j^* b_j}] - \tau_0 B + 0.5\tau_1 B^2 \qquad (15b)$$

In equation (15b), weights w_1, ..., w_k, correspond to the ratio of achievements (optimal interest function in the bargaining process being a first derivative of the strength that is acquired from the threat strategy not to co-operate, (Zusman 1976) minus the reference interest; formally:

$$...; w_j = \frac{(I_j^{opt.} - I_j^0)]}{(I_m^{opt.} - I_m^0)]} = \frac{\partial s(c_j, \delta_j)}{\partial c_j} \qquad (16)$$

Finally, calculating derivatives b_j' of the public welfare function "W" provides a solution:

$$\frac{\partial W}{\partial b_j} = B(1+w_j)[\frac{[p_j x_j^* + C_b^*(x_j^*(1-b_j), \theta_j b_j, \Theta_{0j} - \Theta_{1j} B, r)]}{\sum_{j} x_j^* b_j} + \frac{x_j^*[p_j x_j^*(1-b_j) - C(x_j^*(1-b_j), \theta_j b_j, \Theta_{0j} - \Theta_{1j} B, r)]}{-[\sum_{j} x_j^* b_j]^2}] = 0 \quad (17a)$$

$$\frac{\partial W}{\partial B} = (1 + w_j) \frac{[-C_B'(x_j^*(1-b_j),, \theta_j b_j, \Theta_{0j} - \Theta_{1j} B, r)]}{[\sum_{j} x_j^* b_j]} + [\tau_0 - \tau_1 B] = 0 \qquad (17b)$$

To solve (17), assumptions on functions are needed. We use a reduced form of cost function that depicts land management of farms and EMS; implicitly it contains a substitution. Normally, linear supply and factor demand functions match with quadratic costs. A reduced form is:

$$C(x_j^*(1-b_j),\theta b_j,\Theta B,r)=\gamma_{0j}\theta b_j+0.5\gamma_{1j}\theta b_j^2+\gamma_{2j}\theta b_j r_j+\gamma_{3j}\Theta B+\gamma_{4j}\Theta B^2+\gamma_{5j}\Theta B\theta b_j \quad (17c)$$

For simplification γ_{ij} coefficients cater for scaling, for translation of the EMS into risk reduction, etc. Since they are composed of ecological and economic risk components they reflect farm behaviour. Inserting equation (17b) in (17a) and using the quadratic approximation of individual optimality conditions for farm j we receive for farmer j:

$$(1+w_j)[p_j x_j^* - \gamma_{0j}+\gamma_{1j}b_j-\gamma_{2j}r_j]-[\tau_0-\tau_1[\sum_j x_j^* b_j]]=0 \quad (18a)$$

For convenience we have dropped the coefficients of the eco-impact function (7a and b). Optimisation of the public manager's objective function (17) is a correlate between private farm optimisation and public manager's optimisation reflecting the bargain. However, since bargaining prevails until the number of farmer k, a linear system of k equations exists. For all b_j we get a system that can be solved for $\boldsymbol{b}^{b\prime}=[b^b_1, ..., b^b_j, ..., b^b_k]$

$$\begin{bmatrix}(1+w_1)\gamma_{11}+\tau_1 Ax_1^* & \cdots & (1+w_k)\tau_1 Ax_k^* \\ \tau_1 Ax_1^* & & (1+w_k)\gamma_{1k}+\tau_1 Ax_k^*\end{bmatrix}\begin{bmatrix}b^b_1\\ \cdots\\ b^b_k\end{bmatrix}=\begin{bmatrix}(1+w_j)[p_1x_1^*-\gamma_{01}-\gamma_{21}r_1]+Ax_1^*\tau_0\\ \cdots\\ (1+w_k)[p_kx_k^*-\gamma_{0k}-\gamma_{2k}r_k]+Ax_k^*\tau_0\end{bmatrix} \quad (18b)$$

as a matrix and vector representation. Finally to solve the system, the left hand side can be expressed with a matrix Γ^* multiplied by b^b and the right hand side is a vector given farms "j":

$$\Gamma^*_1 \boldsymbol{b}^b=(1+w)[p-\gamma_0-\gamma_2 r]+Ax_i\tau_0 \Leftrightarrow \boldsymbol{b}^b=\Gamma^{*-1}_1(1+w_j)[p-\gamma_0-\gamma_2 r]+Ax_i\tau_0 \quad (19)$$

The resulting bargaining vector $\boldsymbol{b}^b$ depicts a possible solution. This bargain solution reflects the political power structure w, and $\boldsymbol{b}^b$ also depends on the ecological knowledge of the public manager. If power is equally distributed, a vector $\boldsymbol{b}^s$ can be calculated showing a social welfare solution (dropping weights). In contrast, Figure 3 assumes that the social situation is not achieved. A social objective function is merely theoretically achievable if weights for different pressure groups are equal (a special case). The model can be used to analyse deviations.

5.2 Risk reduction, payments, insurance alternatives and institutions

So far, the analysis has been conducted on the presumption that property rights (Hodge, 1988) were initially ill-defined (no owner of the EMS exists that can buy land from farms and provide nature service in exchange for money) and that a partial manager is in charge of regulatory policy on field margin provision to sustain bio-diversity. However, we could imagine that the community may consider institutional amendments and wants to change the influence of groups on the manager; in particular, after experiencing statutory regulations and political lobbying. Nevertheless, as part of an insurance scheme, payments could be installed and strong contributors to the EMS may become entitled to compensation. In principle, if some farmers concede to pay an amount of money, for instance $\pi_j * B$ (π_j as a portion), profit shares go to other farmers and interest functions change. Money has to be deducted from surplus associated with nature services and economically measured. For instance area provided below the marginal willingness to pay curve (Figure 3) can be redistributed. Administratively, one can think of a uniform premium to be collected in the community of beneficiaries by the manager. But still the size of B has to be decided in political negotiations. Let us assume the community agrees on paying farmers over land shares in the EMS; this would provide them with proportional compensation. Individual payments to or from farm j become noteworthy dependent on farmers' decision to provide a share of land and the total size at given risk:

$$\pi_j \Theta = \pi_j \Theta_{0j} - \Theta_{1j} \pi_j B$$

An introduction of proportional payments enables a re-writing of individual interest functions:

$$I_j^i = \frac{B[p_j x_j^*(1-b_j) - C(x_j^*(1-b_j), \theta_j b_j, \Theta_j^* - \Theta_{0j} + \Theta_{1j} B, r_j)]}{\sum_j x_j^* b_j} + \pi_j^p b_j - \pi_j^n [\Theta_j^* - \Theta_j] \qquad (21),$$

where additionally:

π^p_j = positive premium on buffer zones (profit⇑)

π^n_j = negative premium as insurance to be paid for the pool of finance (profit⇓)

$C(...,\theta^*_j - \theta_j,...)$ = cost reduction on (cost⇓=>profit⇓)

The benefit of this explicit reformulation can be seen in its capability to provide a new bargaining solution. A new $\mathbf{b}^{p}$ includes payments and it implicitly solves for "risk premiums" and "quantities". As special cases, we can compare statutory regulations and mixed pricing.

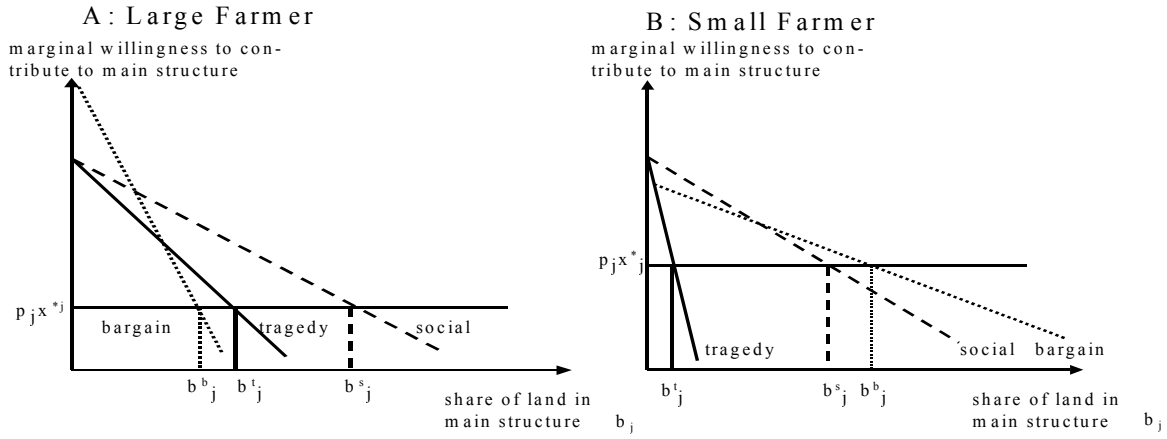


Figure 3: Bargaining solution and modified willingness to contribute after bargaining

6 Summary

The paper has shown that statutory regulations for the provision of field margins in Ecological Main Structures, EMS, can be derived from the application of a political economy framework to a stylized landscape. The EMS supports an eco-system connected to mixed farmland of private fields and common property field margins; then the eco-system is conducive to reduce risk of crop failures. The basic agronomic hypothesis is that an EMS reduces pest pressure: but due to an institutional deficit, in a pure set of private rights, an EMS would not appear. For this we introduce a public management, which is subject to bargaining, and we establish objective functions, which contain field margins. Without common property management, because of the public good character of the EMS, farmers will buy pesticides. In particular, the result of a bargain depends on the political power of the regulator relative to power of farmers. The model allows us to set up hypotheses on an EMS as a natural protector from pests in an ecological and social context. While providing an analysis of expected bargaining processes in field margin provision for an EMS and natural pest control, it assumed that an a-

priori situation of unclear property rights, a so called ill-defined right situation, exists. Though the process of bargaining reveals no actual property right setting itself, amendments to pure public managements, such as payment schemes and changed rights, are mentioned. The impact of power and interest can be distinguished and transaction costs be investigated. The argument is more on common property problems, but ecological effects can be further elaborated.

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