AN ANALYSIS OF FARMERS' BEHAVIOR AND REWARDED PROVISION OF PUBLIC GOODS

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Abstract

Aiming to stimulate the role of agriculture as provider of public goods, the new CAP reform raises many theoretical and practical questions. The most relevant ones concern farmers' response to the policy instruments. This paper uses a formal model to analyse the incentives and constraints generated by policy instruments and their potential impact on farmers' participation decision. The analysis shows that, when choosing policy instruments to stimulate provision of public good, it is important to take into account different degrees and mechanisms of jointness between commodity and non-commodity (potentially public good) production, as they can enhance or erode the desired effect of the policy instruments. Some implications for modelling and policy analysis are discussed.

Keywords

Farmers' behaviour, Provision of public goods, jointness, Common Agricultural Policy (CAP)

JEL Classification:

H41: Public goods
Q12: Microanalysis of Farm Firm
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1. Introduction[1]

The European Union's Common Agricultural Policy (CAP) is continually evolving. Since the 1992 MacSharry reform classical price support has to an increasing extent been replaced by support via direct payments. The 2003 Mid-Term Review (MTR) of the CAP introduced a number of further adjustments to agricultural support. One of the most substantive changes was the introduction of a system of decoupled payments per farm (Single Farm Payment (SFP)) in combination with a (compulsory) cross compliance instrument (EC-Regulation 1782/2003). The latter refers to a system in which the CAP payments are made conditional on farmers meeting Statutory Management Requirements (SMRs) and Good Agricultural and Environmental Conditions (GAEC). Together with the greater decoupling of support payments and the rural development Second Pillar that were introduced in 2003, cross compliance intrinsically sought to promote sustainable agriculture. At the same time, it should help to justify payments to farmers. Moreover, its scope was extended from its original environmental focus to a much wider range of public concerns, each of which was already covered by EU legislation, e.g. animal welfare, food safety, and maintaining agricultural land in a good agricultural and environmental condition.

Acknowledging the importance of agriculture in the provision of certain public goods and the significant amount of support provided by decoupled payments (granted based on historical criteria) raises a debate on how to reform the CAP in such a way that it contributes to achieving a desirable level of public goods. This raises the issue of re-linking and retargeting of the SFPs. Moreover, mid 2011, formal legislative proposals are due about the post-2013 CAP, including new Financial Perspectives. A formal Communication on the future of the CAP after 2013 will be published in the second half of this year and is expected to strengthen the role of agriculture as a provider of public goods. As such the distinction between the first and second pillar of the CAP becomes less clear, since the SFPs (first pillar measure) are likely to be increasingly connected to achieving policy objectives in the sphere of sustainable rural development (typical for second pillar and including for example AES measures).

Implementing a new CAP raises many theoretical and practical questions. For example, is the coupling of CAP funds with public good provision justified? While public good provision is often used as an argument for compensating farmers, some critics consider the payment as hidden government subsidy which will have distortive effect on agricultural production and trade. Further more, if the policy aims to stimulate public good provision, which instruments can better realize the goal of the policy? Should a uniformed payment scheme be preferred to a differentiated scheme? The most relevant ones, however, concern the farmers' response to the instruments. Insight into farmers' possible response to various policy instrument is crucial to assess whether the policies will be sufficient to achieve the policy objectives. How will different policy instruments influence farmers' decision making? What factors are expected to influence farmers' acceptance of policy instruments? How can policy design take into account of these factors?

This paper focuses on a better understanding of farmers behaviour, with a particular focus on explaining what drives their participation in the delivery of certain public goods, and/or their response to payments with a different degrees of targeting (e.g. linked to land, performance criteria, etc.). This will be analysed in a rather formal way to stay away from concrete policy implementations. However, by providing an improved insight into the behavioural mechanisms it aims to contribute to improvements in the modelling and impact assessment analyses of the new kind of policies, as well as to generate some suggestions for policymakers in designing the new policies, which should bring the CAP into the future.

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The paper is organized as follows. Section 2 provides more background to modelling the farmer's decision making process with respect to the provision of public goods. Rather than a standard profit maximization approach a more general and encompassing utility maximization framework is introduced for the analysis. Specific characteristics, such as jointness in production between public and private goods provided by agriculture, are discussed. Section 3 presents the economic model of the farmer, the solution of the farmers optimization problem, and model outcomes associated with specific polities targeted at the provision of public goods. Section 4 discusses a number of lessons and conclusions aimed at improving the modelling of the new CAP and raising some important points that might be relevant in the policy design of the CAP. Finally, Section 5 closes the paper with a number of concluding remarks and some qualifications.

2. Theoretical framework: Concepts and modelling issues

2.1 Utility maximizing framework for farmers' decision making

While farming is a business that interacts with the market through commodity inputs and outputs, agricultural production has distinct features due to the use of natural resources, which often generates externalities and the use of family labour which differs in many aspects from hired labour. The externalities may partake of the character of public goods or bads. The use of family labour means production decision can be jointly made with consumption decision.

An increasing literature suggests that farmer behaviour is not driven only by the maximization of profits (e.g. Defrancesco et al., 2008, Jongeneel et al., 2008, Wynn et al., 2001, Dupraz et al., 2003, Willock et al., 1999). It is well known in economic analysis that behaviour is driven by a rich set of attitudes, values and preferences (Becker, 1993). A strict profit maximization framework fails to encompass other values, beliefs, attitudes and intentions that can greatly influence economic behaviour. A utility maximization framework is therefore used to understand and model producer behaviour with respect to the provision of public goods.

Consider that the agricultural producer's utility is determined by his monetary income (profit from production of marketed commodities, income earned by supplying family labour to off-farm labour market, and net reward from provision of public goods), non-pecuniary benefits from on-farm production activities and leisure. Denote the utility function for a producer *j* as $u^j(I, B, R)$, with:

I = monetary income;

B = non-pecuniary benefits of farm production, modelled as a function of family labour used for on-farm production;

R = Leisure.

The superscript *j* is dropped when only one producer is considered. The form of the utility function is shaped by the farmer's value, attitude, and belief and differs therefore among farmers. Following Key and Roberts (2009), we also use an additive utility function specification, i.e.:
$u(I, B, R) = U(I) + B(h) + R(r)$, where: $I = py + mw - xq - vl - F$, with

p = output price (or vector of output prices in case of multiple outputs),

y = marketed outputs (or vector of marketed outputs in case of multiple outputs),

m = off-farm labour work,

w = wage at the labour market,

x = marketed variable input (or vector of marketed inputs in case of multiple inputs, including hired labour),

q = input price (or vector of input prices in case of multiple inputs),

v = fixed costs per hectare, these are fixed costs related to the use of land,

l = amount of land,

F = fixed costs per farm, examples of the fixed costs are for example maintenance costs of machinery, rent costs for buildings, etc.,

h = family labour used for on-farm production,

r = leisure time.

Further, we impose a number of regularity conditions and assumptions, i.e. $U_I \succ 0, U_{II} \prec 0$; $B_h \succ 0, B_{hh} \prec 0$; and $R_r \succ 0, R_{rr} \prec 0$, indicating a concave utility function and aversion of risk when income or other benefits are uncertain. Family labour is modelled as an allocable fixed input which, when used for agricultural production, can bring non-pecuniary benefits to the farmer. Family labour can also be employed in the labour market (off-farm work), in that case, the producer receives wage income. Hired non-family labour is considered as marketed input.

2.2 Interconnectedness between agricultural commodity and public goods: jointness

For a farmer as producer, provision of public goods is interconnected with agricultural production through the use of production inputs, the particular production mode, or qualities concerning the agricultural commodity. To understand farmer behaviour towards the provision of public goods, it is important to understand the linkage between the provision of public goods and the production of agricultural commodity.

The interconnectedness between standard (private) agricultural commodities and public goods can be viewed from different perspectives. From an output perspective, interconnectedness between public good production and private good production using the same set of inputs might manifest itself in competition or complementarity in their production possibility sets through different forms of jointness in the production technology.

From an input perspective, interconnectedness can result from various sources of jointness in production, which has long been discussed in the academic world, see e.g. Lau (1972), Shumway et al. (1984), and Lynne (1988). Three main sources of jointness are: 1) jointness due to technical interdependency (animal production and manure surplus); 2) jointness in non-allocable inputs (i.e., multiple outputs are obtained from one and the same input, e.g., grassland and meadow); 3) jointness in allocable fixed inputs (e.g., land and labour are typically fixed for one farm but can be allocated to different activities).

2.3 Jointness between production of agricultural commodity and public goods

Jointness in production of agricultural commodity and public goods such as landscape and biodiversity is a widely used argument to provide public support to farmers, as the production of public goods is not paid by the market. More specifically, for this case sometimes the argument is made that the public support can be granted in terms of classical price support to the commodity outputs. To the extent this reasoning is valid it raises an argument to justify the traditional way of support to agriculture.

For a formal analysis of farmer behaviour, jointness between the production of agricultural commodity and public goods requires further formalization. Table 1 presents an overview of different mechanisms of jointness. Considering the jointness of the two production activities through quasi-fixed inputs (land and labour) and other possible technical interdependence, denote the joint production technology as: $F(y,Q,l,h,x;z)=0$, where Q refers to non-commodity outputs (possible public goods that are valued by the society) and z indicates resource conditions such as soil quality. The joint production technology implies a production function for the commodity as: $y = f(l,h,x;z,Q)$, and a production function for the non-commodity good: $Q = g(l,h,x;z,y)$. Both production functions refer to the frontier of the production possibility sets. Depending on the mechanism of jointness between commodity production and the specific public good, production inputs l,h,x may or may not be allocable to the two production activities. When inputs are allocable or distinguishable, they are subscript with '1' for commodity production and with '2' for public good production.

Table 1. Functional jointness between commodity and non-commodity production

Jointness of production	Inputs of production		Modes of production
	Non-allocable inputs	**Allocable fixed inputs**	
Commodity	$y = f(l,h,x;z,Q)$	$y = f(l_1,h_1,x_1;z)$	$y = f_i(l,h,x;z)$, where *i* indicates a production mode.
Non-commodity	$Q = g(l,h,x;z,y)$	$Q = g(l_2,h_2,x_2;z)$, with $l_1 + l_2 = l;$ $h_1 + h_2 = h;$ $x_1 + x_2 = x;$	$Q = g(i)$
Technical relationship	$\frac{dQ}{dy} > 0$	$\frac{dQ}{dy}$ depends on $f(.)$ and $g(.)$	$\frac{dQ}{dy}$ depends on the production mode

The third column of Table 1 represents the case where a farmer can choose between different modes of production, where each mode of production is associated with a specific production of the public good. It should be noted that in reality hybrids between the third column and other column presentations of the production technology will be possible.

3. Analysing farmers' behaviour with respect to the provision of public goods

3.1 Farmer's basis situation without remuneration

To understand the farmer's reference point when considering provision of public goods, it is important to gain insight into farmer's baseline situation without participation in the policy scheme. Consider the basis situation in which there is no remuneration for the provision of public goods, the producer solves his utility maximization problem as follows:

$$\underset{l,h,m,x}{Maximize} \quad u(I,B,R) = U(I) + B(h) + R(r)\,,$$

subject to:
$$l \le A;$$
$$h + m + r = H;$$
$$l, h, m, r, x \ge 0;$$

where: $I = pf(l,h,x,Q;z) + mw - xq - F - vl$ as defined previously, A = total land area (endowment, in hectare), H = total available family labour (endowment, in hours). To simplify the analysis, capital constraint is not considered. Instead, it is assumed that the farmer has perfect access to the capital market and capital is a marketed input with known prices. It should be noted that high debt ratio can lead to solvency problem for the farm. This can be extremely relevant in economic recession when it becomes difficult to obtain credit. Incentive to increase income may outweigh other considerations when there is severe capital constraint. The Lagrangian is:

$$L(l,h,m,r,x) = U(I) + B(h) + R(r) - \lambda(l - A) + \mu(H - h - m - r) \qquad (1)$$

The Kuhn-Tucker conditions are as follows:

a) Land allocation

a1) $L_l = U_I(pf_l - v) - \lambda = 0;$

a2) $\lambda \ge 0;$ (non-negativity constraint)

a3) $l \le A;$ (feasibility constraint)

a4) $\lambda(l - A) = 0;$ (complementary slackness)

b) Labour allocation on farm, off-farm and leisure

b1) $L_h = pU_I f_h + B_h - \mu = 0;$

b2) $L_m = U_I I_m - \mu = wU_I - \mu = 0;$

b3) $L_r = R_r - \mu = 0;$

c) Input use

c1) $L_{x_1} = U_I I_x = U_I(pf_x - q) = 0;$

These conditions can be used to determine the shadow prices of production inputs, which can be seen as the farmer's opportunity costs when allocating these inputs for the provision of public goods.

For land use, if the area of land is not a binding factor, i.e., $\lambda = 0$, condition a1) becomes $U_I(pf_l - v) = 0$. Since $U_I \succ 0$, we have $pf_l = v$, i.e., the farmer should attract or use land for commodity production up to the point where the value of the marginal product equals the fixed cost per hectare. This implies that when the value of the marginal product is lower than the fixed cost (for example, due to low soil fertility or high rent for land, or high land price), the farmer may abandon the land (fallow or sell).

In the case when land is binding, i.e., $\lambda > 0$, satisfying condition a4) means that land will be fully employed in commodity production (i.e., $l^* > A.$). The shadow price of land equals the marginal utility derived from the marginal profit, i.e., $\lambda = U_I(pf_A - v)$. This condition suggests that the opportunity cost of land when allocated to public good production depends both on land use intensity (marginal productivity of land) for commodity production and level of monetary income.

Since farmer's marginal utility decreases with the level of income (i.e., $U_{II} \prec 0$), farmers with higher income would have lower opportunity cost than farmers with lower level of income, given the same level of land use intensity. Similarly, farmers with higher land use intensity have lower opportunity costs than farmers with lower land use intensity, given same level of income. This implies that for the same level of compensation, farmers with higher level of income and high land use intensity will be more prone to accept the compensation than farmers with lower level of income and lower land use intensity.

Similarly, we can derive the shadow prices for family labour. From b1), b2) and b3, we have: $\mu = U_I pf_h + B_h = U_I w = R_r$. The shadow price of family labour is the sum of utility derived from marginal production value and marginal non-pecuniary benefits derived from working on farm. For input use, since $U_I \succ 0$, condition c1) gives $pf_x - q = 0$, which simply states that the value of the marginal product of input equals its market price.

Based on the analysis above, Table 2 summarizes the implied opportunity costs for the farmer in allocating production inputs. This information can be used to identify factors that can influence farmer behaviour. Possible impacts of policy instruments on the allocation of inputs can also be investigated by looking at the comparative statics of the key variables. For example, policy instruments such as area payment has the effect of reducing *v*, the fixed cost of production per hectare. To gain insight on their possible impact on equilibrium labour allocation, we can look at the comparative statics of h and m with respect to the fixed cost *v*. Assuming interior solution, the second order condition gives:

$$L_{hh} = U_{II}(pf_h)^2 + B_{hh} + R_{rr} < 0; \tag{2}$$

$$L_{mm} = wU_{II} + R_{rr} < 0; \tag{3}$$

$$|H| = L_{hh}L_{mm} - (pU_{II} f_h w + R_{rr})^2 > 0; \tag{4}$$

Replacing the shadow price $\mu = R_r = R(H - h - m)$ and total differentiating equation 2) and 3) with respect to h_1, m and v by replacing the shadow price with $\mu = R_r = R(H - h - m)$, using Cramer's rule, we have:

$$\frac{dh}{dv} = \frac{R_{rr}U_{II}(pf_h - w)}{|H|} < 0 \tag{5}$$

$$\frac{dm}{dv} = \frac{U_{II}w(U_I p^2 f_{hh} + B_{hh}) + U_{II}R_{rr}(pf_h - w)}{|H|} > 0 \tag{6}$$

The comparative statics shows that *ceteris paribus*, an area payment that reduces the farmer's fixed per hectare cost of land would increase on-farm labour use and reduces off-farm labour supply. An area payment also influences opportunity costs of land and labour by changing the marginal utility of income. The area payment can therefore in the long run change the production structure (for example, substitution effect of labour and other inputs). It is therefore argued that even decoupled payment can have distortive effect on agricultural production (Key and Roberts, 2009).

Table 2. Farmer's opportunity costs for the provision of public goods

Production inputs	**Opportunity cost**
Land allocation (l)	
$l_1 = A$	$\lambda = U_I (pf_A - v)$
$l_1 < A$	$\lambda = 0$
Family labour (h_1, or r)	
$m = 0$	$\mu = U_I pf_h + B_h = R_r$
$m > 0$	$\mu = U_I w = U_I pf_h + B_h = R_r$
Variable input (x)	$q = pf_x$

In the baseline situation presented above, production of public goods is not explicitly included in the decision problem. A farmer can, however, produce public goods (even although they are not remunerated) because public goods enter the utility function through non-pecuniary benefits. These non-pecuniary benefits can exist due to moral motives such as altruism, responsibility for countryside stewardship, etc. A farmer can also produce public goods even without deriving utility from it, but simply due to the jointness between public goods and commodity. This situation will however change when provision of public goods generates monetary income.

3.2 Farmer's participating decision in policy scheme

Using rational choice theory, the farmer will participate in the policy scheme for the provision of public goods if and only if the participation increases the maximized (overall) utility $u(l^*, h^*, x^*, m^*, r^*, Q^*)$, i.e., $du(l^*, h^*, x^*, m^*, r^*, Q^*) \geq 0$. This requires a close look at the necessary changes that must be made to comply the policy and their net impact on the utility of the farmer. Based on the utility function of the farm, we have:

$$du^* = U_I pf_{l^*} dl + (U_I pf_{h^*} + B_{h^*})dh + U_I wdm + U_I (pf_x - q)dx + R_r dr$$

and from the first order conditions presented in Section 3.1, this becomes $du^* = \lambda dl + \mu(dh + dm + dr)$. The decision rules thus states that a rational farmer will only participate in a policy scheme if the use of quasi-fixed inputs is compensated at least at their opportunity costs. It is therefore necessary to identify the changes the policy instrument would cause to commodity production and compensating them according to their opportunity costs.

Farms and farming practices vary across the country. Heterogeneity of farms and farmers implies heterogeneity of opportunity costs and production possibilities. For example, need for farm labour can have seasonal variation. In peak seasons (e.g., sowing or harvesting), the supply of farm labour will be higher for arable farming.

Many factors influence farmer's opportunity costs through commodity production function. For example, soil quality differs in different area which leads to variations in land productivity. Location of a farm can lead to different transaction costs to the farmer. Location of farm can also determine the potential of the farmer as a provider of public goods. For example, public goods such as landscape and biodiversity are often only possible in certain regions or certain locations.

Some empirical evidence confirms these theoretical insights. For example, Hynes and Garvey (2009) found that relative to good soil types, farmers associated with a poor soil type are more likely to enter the Irish agri-environmental scheme REPS. This highlights the importance of taking into account of unobserved heterogeneity of farm- and farmer-specific characteristics when considering the opportunity costs of participation in voluntary agri-environmental schemes, or of determining the minimum compensation necessary to induce specific groups of farmers, or farmers at a specific location to participate.

3.3 Policy instruments and possible specification of public goods

It is generally accepted that targeted policy steps are required in cases where markets fail to deliver sufficient provision of public goods. Traditionally, economic theory recommends externalities to be 'internalized' through direct control, subsidies and taxes. Payment schemes based on the provision of public goods are already for some time present in the agricultural policy debate (e.g. the CAP's Agri-Environmental (AES) second pillar policies). As another example see Keyzer et al (2003, 37-39) who offers a suggestion and proposal to transform the EU's SFP scheme to a payment scheme for well-defined multifunctional services from agriculture.

Unlike standard commodity outputs, public goods as non-commodity outputs of agricultural production usually do not have well-defined qualities and units. As noted by Cornes and Sander (1996), however, public goods and externalities are incentive structures rather being inherently associated with certain activities. Identification and specification of the public goods is therefore a critical step in designing policy instruments. When choosing policy instruments, it is also important to consider different degrees and mechanisms of the interconnectedness between commodity and non-commodity (possibly public good) production, as they can enhance or erode the desired effect of the policy instruments.

Also the remuneration-schemes need to be specified. In general it makes a difference whether payments depend on efforts made (input use) or outputs delivered (performance based payment schemes). For an example of a spatially differentiated payments scheme see (Hanley et al., 2007). Hanley also used choice experiments to estimate the demand of the public for different public goods. More discussions can be found in Fraser (Fraser, 2009).

A number of common specifications are described below as examples. Depending on the form of the public good and the jointness of production, the inputs (quasi-fixed or variable) are sometimes allocable to the two types of production (for example land reserved for nature conservation). In that case, they are subscripted with '1' if they are used for the production of marketed commodities and '2' for the production of public goods (see also convention used in Table 1).

- Example 1) is a public good that requires special land allocation (for example, land used for water reservoir where commodity production is no longer possible), i.e. $Q = \bar{l}_2$. Two possible reward schemes are distinguished. The reward scheme can be a flat-rate area payment or an area payment with a rate that depends on land quality. In the first case, the production function of public goods is: $Q = g(l_2) = l_2$, which generates an income effect: $S(Q) = sl_2$, where s denotes the payment rate. In the second case, the production function of the public goods becomes $Q = g(l_2, z)$. The income effect in this case is: $S(Q) = \sum_{i=1}^{N} s_i l_{2i}$, where $\bar{s}_i$ denotes the payment rate corresponding to land quality *i* and *N* refers to the total number of land quality types, and l_{2i} representing the amount of land of quality *i* a farmer allocates to public good production.

- Example 2) is a public good that is jointly produced with commodity production, imposing restrictions on the use of variable inputs, for example, fertilizer use. Formally this can be denoted as $Q = g(l, h, \bar{x})$, where $\bar{x}$ denotes the restricted level of input *x*. This example is associated with standards or baselines that are imposed on farmer's production decision. The compliance restricts the form of the production technology for commodity goods. Suppose the restricted production function become $\bar{y} = \bar{f}(l, h, x)$, or restrictions on input use, e.g., $\bar{y} = f(l, h, \bar{x})$. The public goods in this case are defined as:

$$Q = \begin{cases} 0, \textit{ not complying} \\ 1, \textit{ complying} \end{cases}$$

- Example 3) represents a public good that is jointly produced on the land for commodity production, with additional input of family labour and variable inputs, i.e. $Q = g(l, h_2, x_2)$. In practice corresponding to this there might be two types of area payments: a flat-rate area payment and differentiated area payment according to land quality (e.g. also the reward schemes mentioned in Example 1).
- Example 4) is a public good that requires additional family labour and variable inputs, but no additional input of land, i.e. $Q = g(h_2, x_2)$.

3.4 Analyzing farmer's behaviour towards the policy instrument: reallocation of land

As shown in Section 3.3, different types of policy instruments pose different choice problem to the farmer and require correspondingly different analysis. In this section, a policy scheme which requires agricultural land to be allocated to the public good production (field margins or set-aside) is used as an illustration. Assuming that no additional inputs are needed, we assume we have a simple public good production technology $Q = l_2$. The policy scheme requires a maximal land area ($\bar{l}_2$ ha) to be set aside for environmental purposes (e.g. by creating certain buffer zones). The farmer's decision problem now becomes:

$$\underset{l_1, h_1, x_1, l_2, h_2, x_2, m}{Maximize} \; u(I, B, R), \text{ subject to}$$

$$\begin{aligned} &l_1 + l_2 \le A; \\ &h + m + r = H; \\ &l_2 \le \bar{l}_2 \end{aligned}$$

where

$$\begin{aligned} I &= pf(l_1, h_1, x_1, Q; z) + sQ + mw - x_1 q_1 - F - vl_1 \\ &= pf(l_1, h_1, x_1, Q; z) + sl_2 + mw - x_1 q_1 - F - vl_1 \end{aligned},$$

with *s* as the compensation rate for l_2.The Lagrangian associated with this optimization problem is:

$$L'(l_1, l_2, h, m, r, x) = U(I) + B(h) + R(r) - \lambda(l_1 + l_2 - A) - \mu(h + m + r - H) - \sigma(l_2 - \bar{l}_2), \quad (7)$$

where λ, μ and σ are the Lagrange multipliers. The Kuhn-Tucker conditions for this problem are:

a') Land allocation

a1') $L'_{l_1} = U_I I_{l_1} - v - \lambda = U_I (pf_{l_1} - v) - \lambda = 0$;

a2') $L'_{l_2} = U_I I_{l_2} - (\lambda + \sigma) = U_I s - (\lambda + \sigma) = 0$;

a3') $\lambda, \sigma \geq 0$; (non-negativity of land use)

a4') $\lambda(l_1 + l_2 - A) = 0$; (complementary slackness)

a5') $\sigma(l_2 - \bar{l}_2) = 0$; (complementary slackness)

From conditions a1') and a2') , we have: $\sigma = U_I (s + v - pf_{l_1})$, which gives the shadow price of the maximal area $\bar{l}_2$ allocated to the public goods when compensation rate *s*. Setting the shadow price to zero gives optimal compensation rate which satisfies: $s = pf_{l_1} - v$. The optimal rate is therefore determined by the difference between the value of the marginal product of the land and per hectare fixed cost.

b') Labour allocation

b1') $L'_{h_1} = U_I pf_{h_1} + B_{h_1} - \mu = 0$;

b2') $L'_m = U_I I_m - \mu = wU_I - \mu = 0$;

b3') $L'_r = R_r - \mu = 0$;

The first order condition for labour use is the same as in the base situation, i.e. $\mu = U_I pf_{h_1} + B_{h_1} = R_r$. However, equilibrium labour allocation can differ from the base situation since allocating land to public good production can change equilibrium monetary income and lead to substitution of labour for land as production inputs. To see the possible effect of *s* on labour allocation, we can look at the comparative statics of h_1 with respect to *s*. Assuming interior solution and total differentiating condition b1') with respect to *s* and h_1 gives:

$$\frac{dh_1}{ds} = -\frac{U_{II} Pf_{h_1} l_2 + B_{h_1 h_1} + R_{h_1 h_1}}{U_I pf_{h_1 h_1} + U_{II} p^2 f_{h_1}^2} < 0 \qquad (8)$$

This means that a too high compensation rate *s* may decrease equilibrium level of on-farm labour input use.

c') Input use

c1') $L_{x_1} = U_I I_{x_1}^1 = U_I (pf_x - q) = 0$;

Condition c') indicates that the first order condition for input use remains unchanged, i.e., it should satisfy $f_{x^*} = q / p$. This condition reflects the well-known economic insight that in the optimum the value of the marginal product of *x* should equal its market price. However, it should be realized that the restriction of land use may influence the marginal product of *x*. Depending on the production function with respect to the variable inputs, more or less inputs might be used in order to realize the same level of marginal product as in the basis situation. This means participating in the policy scheme will lead to changes in the use of variable inputs even though the same technology is used.

3.5 Expectations on the effect of various policy instruments

Based on the formal analysis, it can be expected that different instruments influence farmer behaviour differently. Table 3 provides a provisional overview of general expectations about how different instruments might affect the provision of public goods as non-commodity production, taking into account different possibilities with respect to the connectedness of private and public good outputs (competition, complementarity, and jointness). These expectations are based on the formal model discussed before which was analysed for a number of different policy instruments, following the same logic as was applied in the previous section. Using the same model as discussed before, it treats individual farmers as price takers, and does not take into account the market effects, as they are likely to arise if all farmers individually or farmers at a massive scale behave in a certain way. So, in order to analyse the full impact of behavioural changes the farm behaviour models should be further complemented by a model taking into account the market effects. Note further that the policy instruments are presented here in a rather abstract way. For a more detailed analysis the policy instruments need to be further specified.

Table 3. A provisional overview of possible effects of policy instruments on provision of public goods with different kinds of interconnectedness between commodity and non-commodity production (based on a farm model-perspective)

Policy instruments	**Interconnectedness of technologies**		
	Use of inputs		**Jointness of outputs**
	Competing	**Complementary**	
Flat-rate payment	Reduce	Increase	Increase
Land quality specific area payment	Reduce	Increase	Increase
Cross compliance (creating public goods by restricting input use or technology for commodity production)	Increase	Reduce	Uncertain
Reward scheme based on outputs of public goods	Increase	Increase	Increase

Introducing a flat-rate payment decoupled with public good provision in general increases the use of land for commodity production as it functions as a subsidy on land (*ceteris paribus*). If land use for commodity production is competing with land use for public good provision, this policy instrument will reduce public provision. On the contrary, if land use for commodity production is complementary to the provision of public good (based on the same land), this instrument will increase the provision of public goods related to the land.

When public good is jointly produced with the commodity goods, increased commodity production will also increase public good production. Similar reasoning can be made to other policy instruments to derive their possible effects on the provision of public good. Reward schemes, which directly remunerate the public good activity or production, are likely to increase the supply of the public good. In practice, however, it might be rather difficult to implement such policies because of difficulties to clearly delimit, measure public goods.

4. Discussion

4.1 Some implication for research and modelling

It should be noted that this paper has an analytical focus. As such it does not yet provide insight into the empirical importance of the various issues. In order to achieve that an empirical follow-up is recommended to create a more complete and realistic picture. However, usually such an empirical assessment would involve the use of models, which currently are often sector models originally built to assess market and price, and trade policies. In general these models (still) lack an adequate representation of public good provision and the generation of positive and negative externalities by agriculture[2]. This paper contributes to the issue as to how properly model public good activities. In case of strict jointness of public good provision activities or externalities with traditional farming activities, in modeling this linkage can be easily exploited by connecting them to traditional activities which are already modeled. When there is no jointness, there is an argument to include new (public good and externality) activities in the models, which interact with the traditional activities into the existing models. Moreover, farmers' decision making with respect to these activities should be derived from a consistent choice theoretical framework, just like that is normally done for traditional farming activities such as food and feed production.

As the analysis showed, not only the regular variables explaining economic supply activities (such as output and input prices) are important in explaining farmer participation in public good provision schemes, but also the contract specification is crucial, since it is this that determines the opportunity costs of participation. It was argued that this relationship is complex. However, given that the basic mechanism is understood, the framework provides in this study might also be a guide to more simplified (or reduced form) approaches.

4.2 Selected implications for public good policy

In general positive and negative externalities lead to a suboptimal allocation because the market fails to take externalities properly into account. However, the mere existence of externalities related to agriculture is not sufficient to justify government interference. In case the impacts of the externalities spread to large numbers of victims or beneficiaries, government interference might in principle be relevant. The standard way suggested by the economic literature is to restore optimality in case of externalities is by introducing incentive policies, in particular Pigovian taxes (negative externality) and subsidies (positive externality) and impose these with respect to the generator(s) of the externalities[3]. However, introducing (general) price distortions (for example by creating import tariffs and export subsidies) is in general not an optimal solution in this case. This is because prices and price distortions

[2] Here the focus is on public good provision by agriculture. The (negative) externalities issue also challenges the current modeling tools in another sense. Rather than having economic or agronomic-environmental models, there is an increasing need to have models which integrate both aspects, which requires an intensified interaction and collaboration by economists, agronomists and environmentalist and ecologist researchers. Two examples along this line are the EURURALIS and CAPRI-MITERRA (used in CCAT an EU Sixth Framework Program project on cross compliance standards) modeling frameworks. Further exploration of this issue is beyond the scope of this paper.

[3] Agri-environmental schemes (for nature, wildlife and landscape preservation) can be interpreted as operationalization of the Pigovian subsidy principle.

treat supplies and demanders in a symmetric way, whereas in this case an asymmetric treatment is required for optimality[4].

It can be argued, however, that within the WTO's trade negotiation framework, the issue of public goods should be recognized. This implies that member states should have freedom with respect to the Pigovian taxes and subsidies instrument, even though it is acknowledged that this will influence a country's trade position. Note that the language might be a bit confusing here: a Pigovian subsidy, for example, is when properly targeted no subsidy in the strict sense of the word, but rather a compensation for services delivered (equivalent with normal prices). It should be noted that from a social welfare maximizing point of view it is in general not optimal to subsidize victims (of negative externalities) or tax beneficiaries (of positive externalities). Incentive policies should only focus on the generators of the externalities. As a consequence of the foregoing, using payment schemes, which let the beneficiaries of positive externalities (public goods) pay for their consumption or enjoyment of the benefits derived from the externality (for example to general money for compensating the farmers) is generally inefficient. It will reduce or inhibit the consumption of the public good to suboptimal levels (too few consumers might benefit from it).

The foregoing result does not imply that voluntary private donations, aimed to ensuring or encouraging public good provision by agriculture, that are made to farmers conditionally on them taking certain actions generating the externality might be suboptimal. If there is no government interference private payment schemes are most likely to be welfare improving relative to the free market equilibrium. However, they in general will be insufficient to achieve a full welfare optimum. As such private schemes are at most incomplete alternative for government interference.

5. Concluding remarks

Using a formal approach, this paper analyzed farmer's decision making with respect to policy instruments aiming to stimulate the provision of public goods. Significant attention was paid to concepts and production technology. With respect to the latter in particular the degree of jointness appeared to be crucial. Private and public outputs can be complementary, independent, or competing. As a general point, the results emphasize the need to carefully analyze how the public outputs are produced and their way of interaction with the private output. There is also a link from this to the determination of a proper remuneration of public good provision activities.

Introducing a flat-rate payment decoupled with public good provision turned out to in general increase the use of land for commodity production as it functions as a subsidy on land (ceteris paribus). If land use for commodity production is competing with land use for public good provision (e.g. idled or set-aside land), this policy instrument will reduce public provision. On the contrary, if land use for commodity production is complementary to the provision of public good (based on the same land), this instrument will increase the provision of public goods related to the land. When public good is jointly produced with the commodity goods, increased commodity production will also increase public good production. Similar reasoning can be made to other policy instruments to derive their possible effects on the provision of public good. Reward schemes, which directly remunerate the public good activity or production, are likely to increase the supply of the public good. In practice it might however be rather difficult to implement such policies because of difficulties to clearly delimit and measure public goods.

Since our analysis focused on the supply side the public transaction costs associated with designing and operating incentive policies (relative to regulatory policies) are beyond the scope of the current paper, but could be an important consideration from a policy maker perspective to rely in certain cases on regulatory policies rather than incentive policies.

[4] In case of significant transaction costs there could be a reason to deviate from this line (see Vatn, 2002).

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