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MULTIFUNCTIONALITY OF AGRICULTURE: AN INQUIRY INTO THE COMPLEMENTARITY BETWEEN LANDSCAPE PRESERVATION AND FOOD SECURITY

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Multifunctionality of agriculture: An inquiry into the complementarity between landscape preservation and food security

by

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Abstract:

Without support, the levels of agricultural public goods will fall short of the demand in high cost countries like Norway, Finland and Iceland. However, as demonstrated in this paper using Norway as a case, the current support and agricultural activity is far out of proportions from a public goods perspective. Model simulations show that at most 40% of the current support level can be defended by the public good argument. Furthermore, the present support, stimulating high production levels, is badly targeted at the public goods in question. Since agricultural land is a major component of both food security and landscape preservation, thus giving rise to a high degree of cost complementarities between the two public goods, it would be more efficient to support land extensive production techniques, than production *per se*.

Keywords: Food security, landscape preservation, public goods, agricultural policy, numerical model.

1. Introduction

It is widely accepted that there are externalities and public goods related to agricultural activity, such as the amenity value of the landscape, food security, preservation of rural communities and rural lifestyle, cf. Winters (1989-1990) and more recently Peterson et al. (2002) and Hediger and Lehman (2003). However, the issue is about what implications these externalities should have on national agricultural policy. What support levels can be defended by the so-called multifunctional role of agriculture, and what policy instruments are efficient? In the ongoing WTO negotiations, for example, many high cost countries use the multifunctional aspect to argue for continued high support levels, even in the form of tariffs and output subsidies. Other low cost countries reject such arguments as protectionism. The latter view finds support in a recent contribution from Peterson et al. (2002), who derive the efficient set of policies for a multifunctional agriculture, and show that efficiency cannot be achieved through output subsidies.

This paper offers an empirical contribution to the multifunctional aspect of agriculture. In earlier papers we have examined the food security and landscape preservation arguments as separate issues. In Brunstad et al. (1995a) the food security argument was discussed. A numerical model was applied to compute what Norwegian agriculture would look like if the only purpose of support was to provide food security. Compared to the actual activity in agriculture, the analysis indicated a decline in employment and land use of about 50 %. In (Brunstad et al, 1999), the landscape preservation argument was examined. A method for incorporating information on the willingness to pay for landscape preservation inferred from contingent valuation studies, was presented, and implemented in the objective function of the model mentioned above. To illustrate the method the Norwegian agriculture was used as a case, and optimal levels of production, land use, employment and support were calculated. Based on various simulation experiments it was indicated that only a minor fraction of today's generous support level would be upheld, and production and employment would drop to low levels. However, even if the landscape preservation argument was not able to defend today's levels of production and employment, it was strong enough to keep a substantial part of today's agricultural surface under cultivation.

In this article we discuss the optimal policy when food security and landscape preservation are simultaneously taken into account. To what degree are these public goods complementary in the sense that supplying one of them more or less automatically would lead to supply of the other(s)? How much support is necessary to sustain reasonable levels of public goods and what policy instruments are efficient, when cost complementarities are considered?

In section 2 we demonstrate some basic principles on food security, landscape preservation and cost complementarities within a simplified framework. In section 3, these principles are elaborated into a richer model. A willingness to pay function for landscape preservation and a production function for food security are incorporated into a sector model for the agricultural sector in Norway. The model is, in section 4, employed to discuss the optimal policy and supply of public goods when cost complementarities are considered. Section 5 offers concluding remarks.

2. Agricultural public goods: Concepts and principles

In this section we demonstrate some basic principles on food security, landscape preservation and cost complementarities within a simplified framework. Later, these principles are elaborated into a richer model.

2.1 *Food security*

An agricultural sector that is too small may cause problems for the population if a crisis should arise. Blockade in connection with war or international conflict is the traditional example of a crisis. Increased risk of ecological crises and man-made disasters like the Chernobyl fall-out are perhaps more relevant examples. The ability to provide food if a crisis arrives is referred to as (national) *food security*. Ballenger and Mabbs-Zeno (1992) defines it more precisely as:

$$(1) \qquad Pr\ [(\text{production} + \text{stocks} + \text{imports} + \text{aid}) \geq \text{needs}] \geq \pi,$$

where Pr symbolizes probability, π is the minimum acceptable likelihood and 'needs' is the subsistence level. This level has to be covered either from national production or from imports and stockpiling. In Brunstad et al. (1995a) the subsistence level is measured by a *crisis menu,* defined as the minimum annual quantities of agricultural products that must be made available for the population when some consideration is also taken to the palatability of the diet. If it is not possible to import, this consumption must be covered from domestic production. Stockpiling is possible for storable commodities, but with no import possibilities stocks will soon run out. Such arguments have traditionally been the rationale for self sufficiency or near self sufficiency in food production.

The Gulbrandsen-Lindbeck principle

Gulbrandsen and Lindbeck (1973) attacked the self sufficiency goal by stressing that production in normal times does not have to be equal to the production during a crisis. Some switching of production when the crisis has arisen will be possible. The crucial condition for switching of production is, however, that the necessary factors of production are available, especially agricultural land but also skills, animal material and capital equipment.

The following simple example clarifies the Gulbrandsen-Lindbeck principle. Assume that we have two agricultural commodities X_1 and X_2, which only needs land, L, to be produced. There is international trade in both commodities, so they can be bought and sold to world market prices $P_{x_i}^{w}$, $i=1,2$. The production technology is assumed to be Leontief, i.e.

(2) $$X_i \leq \frac{1}{\gamma_i} L_i, \quad i=1,2,$$

where γ_i is an input-output coefficient and L_i is the land used in the production of commodity i. Land is limited, i.e.

$$\sum_i L_i \leq \overline{L}\ .$$

In figure 1 we have drawn the production possibility frontier PP. The slope of PP equals $-\gamma_2/\gamma_1$.

Suppose that the crisis menu is given by $X^M = (X_1^M, X_2^M)$ marked as A in the figure. The land requirement for producing X^M is denoted L^M, and the production possibility frontier given this land requirement is the solid line MM.

Assume that we choose a level of land use that is not sufficient to guarantee complete food security, thus we are only able to produce a share, λ, of the crisis menu. Define $X=(X_1,X_2)= \lambda X^M$. For the moment we abstract from stockpiling and aid, and imports of the two commodities, μ_i, is treated as uncertain. (1) can then be written as:

$$Pr(X+\mu \geq X^M) \geq \pi; \qquad \mu \geq 0,$$

where $\mu=(\mu_1, \mu_2)$. $Pr(\lambda X^M+\mu \geq X^M)<1$ for $\lambda<1$, and the probability is 1 when $\lambda \geq 1$.

The point of departure for Gulbrandsen and Lindbeck is an inefficient agricultural sector. This means that the *net cost per hectare land*, NCH_i, is positive:

(3) $$NCH_i \equiv P_l - P_{x_i}^w \frac{1}{\gamma_i} > 0$$

for both commodities. Without support nothing will be produced. Food security is an argument for agricultural support, i.e. land must be available when a crisis arises.

Assume that it is more costly (per hectare) to produce X_1 than X_2, so $NCH_2 < NCH_1$, and assume that we require complete food security (λ=1).

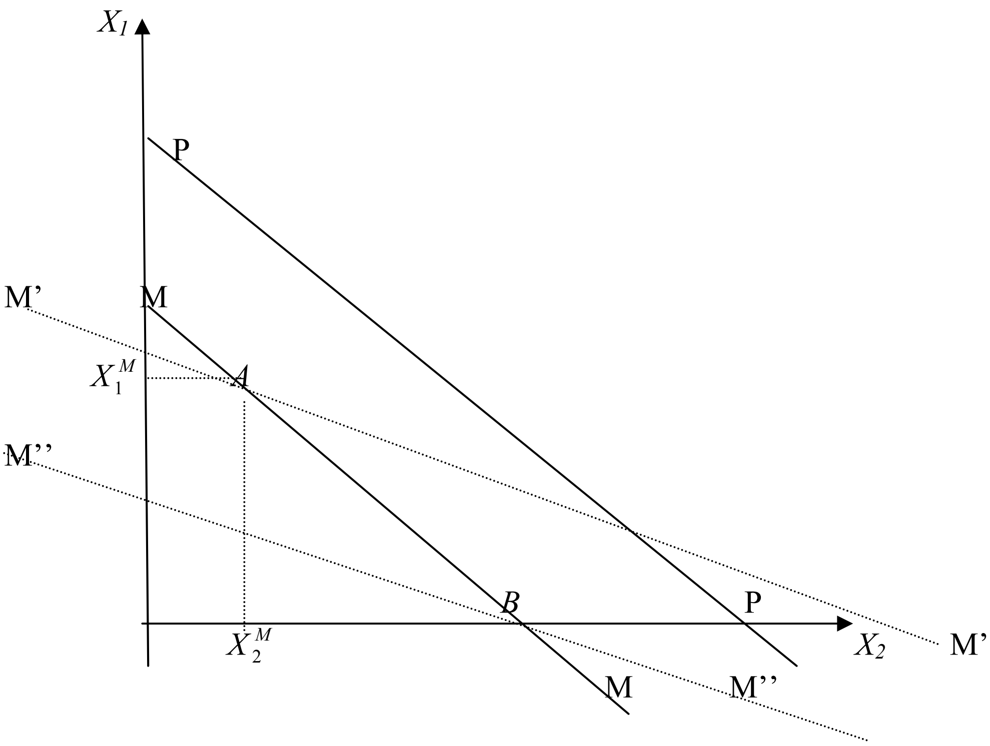


Figure 1: *Production possibilities in the agricultural sector*

The "self-sufficiency-principle" would imply production in A at a cost corresponding to the line M'M' (with a slope equal to $-NCH_2\gamma_2/NCH_1\gamma_1$). The *Guldbrandsen-Lindbeck principle* says that in normal years the most efficient way to guarantee the provision of L^M is to produce in the point marked as *B,* corresponding to the dotted line M''M'' going through this point.

Assume that we choose a level of food security equal to λ^1, $0<\lambda^1<1$, which corresponds to a level of land use equal to $L^1 < L^M$. Given our assumptions, the minimal governmental cost, *NC*, for providing such a level of food security equals:

(4) $NC=NC(L^1) =[NCH_2]L^1.$

For complete food security the net cost is $NC^M=NC(L^M)$.

2.2 Landscape preservation

An additional argument for agricultural support is the amenity value of the landscape. This is grounded in the value of an open and varied landscape, sustained by agricultural production. We follow Lopez (1994) and assume the following willingness to pay function for landscape preservation:

(5) $$WTP = E[LP]^{\varepsilon}$$

where E (>0) is a constant, LP is an index of amenity enhancing agricultural land which we in this section assume is equal to the use of land for agricultural production, L. ε reflects the marginal willingness to pay for landscape preservation and since we assume $\varepsilon<1$, the function in (5) conforms to the standard assumption of being increasing and concave in LP.

If the amenity value of the landscape is the only external effect, the optimality condition is that agricultural production should expand as long as the marginal willingness to pay exceeds net cost per hectare, i.e.[1]

$$NCH_2 = MWTP \equiv \varepsilon E L^{\varepsilon-1}.$$

Figure 2 illustrates the optimal solution. The necessary rate of subsidy is marked as NCH_2. Since the available production techniques are Leontief, NCH_2 is a straight horizontal line. The marginal willingness to pay for landscape preservation, $MWTP$, is given by the convex curve. Marginal willingness to pay is large when the agricultural activity is low, and diminishes with increased agricultural activity. The optimal land use equals L^{LP}.[2]

[1] The condition is derived from the problem $\underset{L_1,L_2}{Max}\left(P_{x_1}^{w}\frac{1}{\gamma_1}L_1+P_{x_2}^{w}\frac{1}{\gamma_2}L_2-P_l(L_1+L_2)+E(L_1+L_2)^{\varepsilon}\right)$, and we impose the assumption that $NCH_2<NCH_1$.

[2] In the case of a profitable agricultural sector, $\overline{L}$ is the optimal solution. Food security and agricultural landscape will then be provided freely as side effects from the activity in the agricultural sector.

2.3 Cost complementarities

Assume now that in addition to landscape preservation, complete food security shall be provided. This means that L^M must be used in production of agricultural commodities. L^M is marked into figure 2, where it is assumed that $L^M > L^{LP}$. In this case food security dominates landscape preservation, and it is not optimal to use more land than L^M.[3] The reason is that *MWTP* is less than the per hectare cost in production in L^M.

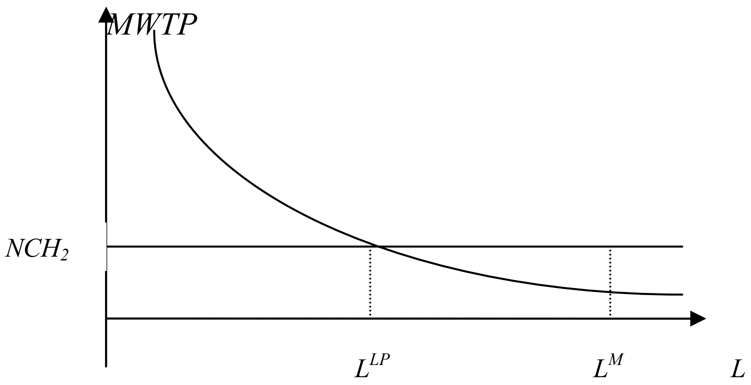


Figure 2: *Optimal solution with public goods*

The figure brings us to the concept of jointness in production. In general, joint production exists if the production of two or more outputs is interlinked in some way, e.g. through technical interdependences or non-allocable inputs (see Peterson et al, 2002). Jointness gives rise to cost complementarities, also referred to as economies of scope, which means that it is more expensive to produce the outputs separately than together.

For agricultural public goods, jointness is mainly related to the existence of non-allocable inputs. By definition it is difficulty to determine a non-allocable input's contribution

[3] If there is willingness to pay for land use in excess of L^M , subsidies must be paid to achieve landscape preservation. Then food security is provided freely, without extra payment.

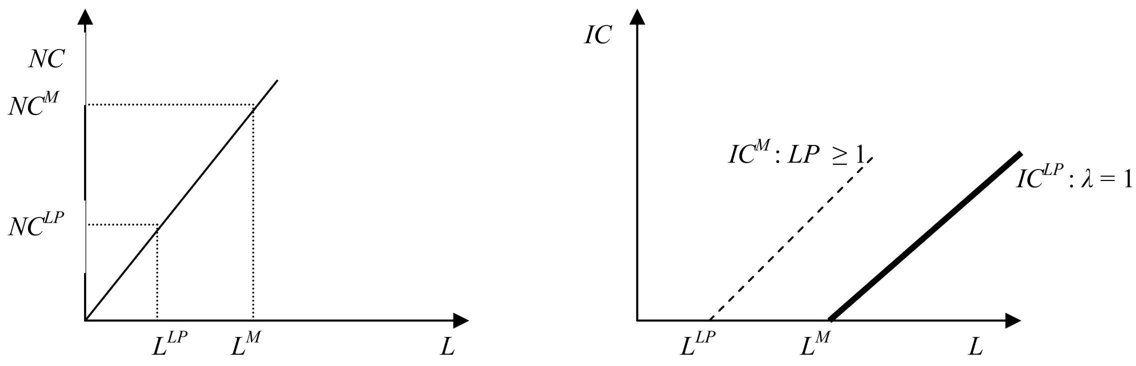
to each output. In agriculture, land is the most obvious non-allocable input since land enters into the production of both landscape preservation and food security, as well as private goods. But also labor and animal material have such characteristics. Besides being key inputs in production of food, these inputs contribute to food security and they affect the amenity value of the landscape.

If we return to our simplified framework with land as the only input, (4) gives the net stand alone costs of providing food security. This relationship is drawn into figure 3a. Due to our simple production technology, the net stand alone cost of producing landscape preservation coincides with the drawn cost curve. If we use L^M in the production of food security and L^{LP} in the production of landscape preservation, the sum of the net stand alone costs are: $NC(L^M) + NC(L^{LP})$. In this case the cost from joint production is: $NC(L^M)$. The percentage increase in costs if the production of the two goods is split into separate processes compared to joint production is then:

(6) $$c = 100\frac{NC(L^M) + NC(L^{LP}) - NC(L^M)}{NC(L^M)} = 100\frac{NC(L^{LP})}{NC(L^M)}$$

Thus, c is a measure of the degree of cost complementarities between food security and landscape preservation, for given prices of private goods. If c=0, there is no cost complementarities.

The existence of cost complementarities can also be visualized by reference to the incremental cost concept. The solid line in figure 3b illustrates the incremental cost of increasing the supply of landscape amenity values (IC^{LP}) if we have complete food security (L^{M}). Up to L^M, landscape values are produced freely. However, if the society demands more landscape values, an incremental cost incurs. *Visa versa*, the dotted line in figure 3b is the incremental cost of producing food security (IC^M) for a given minimum level of landscape preservation, L^{LP}.



a) Net stand alone cost b) Incremental cost

Figure 3: Cost curves for public goods

3. An agricultural model with public goods

To quantify costs of providing public goods as well as cost complementarities, we need to elaborate the basic principles put forward in the previous section into a richer model. As a point of departure, we use a sector model for the agricultural sector in Norway.[4] This model is extended by incorporating a willingness to pay function for landscape preservation, and by adding a production function for food security.

3.1 The core model

The model, which base year is 1998, covers the most important commodities produced by the Norwegian agricultural sector, in all 13 final and 8 intermediary product aggregates. Of the final products, 11 are related to animals while 3 are related to agricultural crops.

Inputs needed to produce agricultural products are land, labor (family and hired), capital (machinery and buildings), concentrated feed, and an aggregate of other goods. Furthermore, we distinguish between tilled land (*T)* and grazing on arable land and pastures (*G*), so

$$G + T = L \leq \overline{L}.$$

Domestic supply is represented by about 400 "model farms". Each model farm is characterized by Leontief technology, i.e. with fixed input and output coefficients. However, production can take place on small farms or larger more productive farms. Consequently, there is an element of economies of scale in the model.

The country is divided into nine regions, each with limited supply of different grades of land. This introduces an element of diseconomies of scale because, *ceteris paribus*, production will first take place in the best regions.

Domestic demand for final products is represented by linear demand functions. Economic surplus (consumer's surplus plus producer's surplus) of the agricultural sector is maximized, subject to demand and supply relationships, policy instruments and imposed

[4] An earlier version of the model is described in Brunstad and Vårdal (1989), but the model has been considerably improved upon since then. A technical description of an earlier version of the model is given in Brunstad et al. (1995b). Details are given in Gaasland et al. (2001). The model is constructed in order to perform policy analyses, and has as such been used by the Norwegian Ministry of Finance and the Norwegian Ministry of Agriculture.

restrictions. The solution to the model is found as the prices and quantities that give equilibrium in each market. A broader description of the model is offered in the appendix.

3.2 Landscape preservation

Landscape preservation is taken into account by adding the willingness to pay function (5)

$$WTP = E[LP]^{\varepsilon}$$

to the economic surplus as defined in the previous paragraph. The amenity value of tilled land, T, is allowed to differ from that of arable land and pasture, G. The aggregate for landscape preservation is postulated by the following CES function:

$$LP = A\left[\alpha_G G^{(\kappa-1)/\kappa} + \alpha_T T^{(\kappa-1)/\kappa}\right]^{\frac{\kappa}{(\kappa-1)}}.$$

Following Brunstad et al. (1999), the parameters $E, A,$ α_G and α_T are calibrated to estimates of amenity benefits taken from the research of Drake (1992). Based on the research of Lopez et al. (1994), the elasticity of scale, ε, is set to 0.172. This means that the marginal willingness to pay is strongly decreasing for rising levels of LP. Moreover, the elasticity of substitution between cultivated pasture and tilled land, κ, is assumed to be equal to 3.0, reflecting a relatively high degree of substitution.

3.3 Food security

Food security, FS, is represented in the model by the nested CES function:

(7) $$FS = \left(\beta_L L^{(\sigma-1)/\sigma} + \beta_S S^{(\sigma-1)/\sigma} + \beta_A A^{(\sigma-1)/\sigma}\right)^{\sigma/(\sigma-1)},$$

where S is skilled labour and A is a CES aggregate of animal products, defined as:

(8) $$A = \left(\chi_M M^{(\mu-1)/\mu} + \chi_E E^{(\mu-1)/\mu} + \chi_C C^{(\mu-1)/\mu}\right)^{\mu/(\mu-1)}.$$

Here, M is meat products, E is egg and C is cow milk. $\beta_i > 0$ ($\forall\, i = L, S, A$) and $\chi_j > 0$ ($\forall\, j = M, E, C$) are distribution parameters. σ and μ are the substitution elasticities in the first and second level of the function, respectively.

The function says that a certain level of food security can be obtained if certain levels of acreage, labour (i.e. agricultural skills) and animal production (i.e. animal material) are available. Furthermore, animal production is split into meat, egg and milk. If we allow for positive substitution elasticities, then the same level of food security can be provided by different combinations of the various components. An important special case is when the substitution elasticities are set to 0. The CES functions in (7)-(8) then collapse into Leontief types.

To calibrate the distribution parameters of this function, we need to know the cost share (quantity and unit cost) of each of the components for a defined level of food security. In this respect, we use the crisis menu[5] in table 1, and normalize the level of food security that corresponds to the crisis menu to $FS = 1$. The menu provides sufficient vitamins, minerals and proteins for the yearly subsistence needs of the population. If we take into account that there exist ample quantities of sugar through stock-piling, this menu also provides sufficient kcal for the population. Compared to normal consumption the menu involves higher consumption of vegetable in proportion to animal products. Consumption of milk, meat and eggs is strongly reduced, while the consumption of grain and potatoes is kept at a relatively high level. In addition, the crisis menu makes allowance for the fact that consumption of fish, of which Norway has a huge export surplus, can be considerably increased.

Table 1: Crisis menu compared to actual consumption in the base year 1998

	Consumption 1998	Crisis menu
Grains	463	335.0
Potatoes	309	460.6
Cow milk	1400	852.7
Meat	247	62.8
Eggs	44	16.7
Fish	-	335.0

Note: Values are expressed in million kg per year.

[5] This table is taken from a government report (NOU, 1991, p. 142). We have reestimated the figures found in this report to a 1998-level.

The crisis menu indicates the minimum annual quantities of agricultural products that must be available for consumption in times of crisis.[6] However, according to the Gulbrandsen-Lindbeck-principle, production in normal times does not have to be equal to the necessary production during a crisis. Some switching of production when the crisis has occurred will be possible. This requires that essential factor of production are available, especially acreage, skills and animal material, as indicated by the function (7) and (8).

In line with the Gulbrandsen-Lindbeck principle, we first employ the agricultural model to calculate how much acreage (L_0) and labor (S_0) that is needed to produce the quantities of food required by the crisis menu. These levels, calculated to be 56% (L_0) and 29% (S_0) of the base levels, must be kept continuously available in order to be prepared to produce the crisis menu if the needs arise. In addition to keeping land and skilled labor available, an animal stock has to be available for meat and milk production. This limits the extent to which the current production of animal products can be reduced relative to the crisis menu. This is taken care of by assuming that the production of meat (M_0), cow milk (C_0) and egg (E_0) must not fall below the levels of the crisis menu.

The quantities derived above are employed to calibrate the distribution parameters of the function. However, to find cost shares we also need to know the unit cost of each component. For this aim, we implement a minimum restriction on each component equal to the quantity level. The unit cost follow from the shadow price.

Preferably, the substitution elasticities (which are free parameters) should be based on empirical estimates. However, in absence of such estimates we have to rely on judgment. At the first level we assume that the elasticity is quite low (σ = 0.5). Thus, acreage, labor and animal material can only to a minor degree substitute for each other without depreciating food security. On the second level, it is likely that the possibilities to substitute are higher, since it is of minor importance from what source the proteins and the animal fat come from (meat or milk). Here, we apply an elasticity of μ = 2. Note, that between different meat products (beef, sheep, pig and poultry) we implicitly assume perfect substitutability.

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[6] Stockpiling and remaining import possibilities will make it possible to reduce domestic production below this level. Thus, a crisis of relatively long duration can be withstood with lower levels of production than those indicated in table 1.

4. Quantifying complementarities – model results

The model is calibrated to reproduce the actual situation in the base year 1998 as closely as possible, by including the actual support and tariff regime. Column 1 of table 2 presents the base solution. In spite of climatic disadvantage, production is high (and import low). Norway is self-sufficient in most products, and for dairy products there is even a surplus which is dumped on the world market. The exception is grain. The arctic climate does not permit sufficient quantities of high quality grain for bread-making. To sustain these high activity levels, substantial support is necessary (15.2 billion NOK or 1.83 billion €).[7] Since agriculture employs about 59,700 man-years, the support per man-year is about 255,000 NOK (30,700 €)[8].

Column 2 gives results of a simulation where landscape preservation is the only policy objective. Landscape preservation is implemented in the model as described in section 3.2. Compared to the base solution, the activity in the agricultural sector is substantially reduced, especially production and employment (16% of level in the base solution). Naturally, since land use enters into the WTP function it declines less than the other indicators. Nevertheless, the computed level of land use is only 43% of the present level. Land intensive grazing, i.e. extensive sheep farming, keeps up better than grain production on tilled land. Necessary support is 3.3 billion NOK, or about one fifth of the support in the base solution.

Note that food security as well as private goods (food), follow as by-products of landscape preservation. More specifically, the index for food security is 37% of the crisis menu level. This emphasizes the joint-product nature of agricultural activity. The agricultural land that enters into production of landscape amenity values, contributes also to food security,

In the next simulation, reported in column 3, we ignore landscape preservation and concentrate solely on food security. Here we include a constraint in the model saying that the level of food security has to be equal to or greater than 1 ($FS \geq 1$). In other words, we require complete food security ($\lambda \geq 1$). No other regulations or support systems are imposed.

Naturally, the restriction is binding, which means that food security is not a free good. However, this level of food security can be provided at a considerable lower cost than is the case today. Agricultural support decreases to 5.5 billion NOK, or about one third of the base solution. Employment and land use decline to 29% and 57% of the base line levels. Compared to the landscape preservation scenario, however, activity levels are higher, especially production and

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[7] We have used the exchange rate 1€=8.30NOK, which was the exchange rate that gave approximately purchasing power parity between Norway and EU in 1998.

[8] Both total support and employment figures are somewhat lower than the actual ones. Support per man year, on the other hand, is approximately correct.

employment, but also land use. This reflects the fact that food security requires a wider specter of inputs than landscape preservation. Note that food security dominates landscape preservation, i.e. the level of landscape preservation that follows as a by-product of complete food security is higher than in the previous solution (LP = 1.33).

Looking more closely at the food security solution, we observe that it is optimal to have a production in normal times that differs from the requirements of the crisis menu. Grain production is reduced and is far below the levels required by the crisis menu. Relative more of the acreage is applied to milk, meat and egg production. Also, for meat there has been a switch to land intensive production techniques. Extensive production of sheep meat absorbs parts of the land now used for grain production. If a crisis occurs, animal production will gradually have to revert to grain production while grain stocks are running down.

We now take food security and landscape preservation into account in the same model simulation. Thus, the WTP function for landscape preservation is added to the objective function, and the level of food security must be equal to or exceed a floor of 1. Compared to the food security alone solution, we see that adding willingness to pay for landscape preservation results in higher land use (+12%), while employment is only slightly affected (-2%). A further switch towards land intensive techniques takes place, represented by the increase in extensive sheep meat production. Observe that the level of landscape preservation is 50% higher than in the landscape preservation alone solution. This reflects the existence of complementarities between the two public goods: Due to common inputs, support to obtain a desired level of food security also reduces the costs of keeping up the cultural landscape.

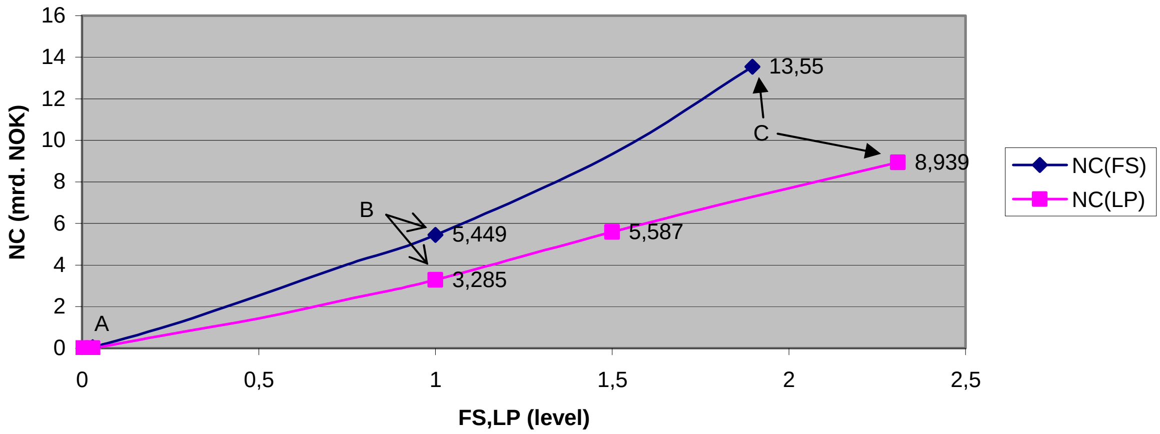
Cost functions for public goods are presented in figure 4 and 5. Figure 4 shows net stand alone costs (NC) of providing landscape preservation and food security, respectively, while figure 5 gives incremental costs (IC) of increasing the supply of one public good (e.g food security) when the level of the other public goods (e.g. landscape preservation) is equal to or higher than 1.

Table 2: Production and main input levels in Norwegian agriculture.

	Base Solution	**Landscape preservation**	**Food security**	**Landscape preservation and food security**
Production (mill. kg/ltr)				
Milk	1671.5	139.1	832.1	709.6
Beef and veal	82.1	5.6	33.6	28.6
Pig meat	100.1	-	-	-
Sheep meat	23.0	28.0	18.4	29.7
Poultry meat	27.8	-	14.8	-
Eggs	43.8	-	16.7	9.8
Wheat	210.5	114.8	151.1	150.0
Coarse grains	1021.3	255.1	367.8	339.1
Potatoes	298.0	310.3	307.1	312.3
Land use (mill. hectares)	0.85	0.36	0.48	0.54
Tilled land	0.31	0.09	0.13	0.12
Grazing and pastures	0.54	0.27	0.35	0.42
Employment (1000 man-years)	59.7	9.8	17.3	17.7
Economic surplus (billion NOK)	36.7	45.7	44.8	45.0
+ Consumer surplus	21.9	29.7	30.0	30.3
+ Value landscape	22.3	19.3	20.3	20.7
+ Producer surplus	1.1	-	-	-
- Budget support	8.6	3.3	5.5	6.0
Total support (billion NOK)	15.2	3.3	5.5	6.0
Border measures	6.7	-	-	-
Budget support	8.5	3.3	5.5	6.0
Landscape preservation	2.31	1	1.33	1.49
Food security	1.90	0.37	1	1

In point A of figure 4, *NC* = 0 for both public goods, which means that no support is given. In this case, almost no public goods are produced. This reflects the fact that the Norwegian agriculture is unprofitable at world market prices. The points marked B in figure 4, give *NC* that corresponds to a level equal to 1 for each public good. These numbers are equal to the reported budget support in column 2 and 3 of Table 2. Finally, C reports *NC* for the levels of public goods in the base solution. Not surprisingly, the achieved levels of public goods are high in the base solution. The index for landscape preservation is 131% higher that the level reported in column 2, while the level of food security overshoots the needs derived from the crisis menu, reported in column 3, by 90%. Also, the costs exceed the amounts in point B by about 160%. Thus, it seems clear that the present high level of support only to a minor degree can be defended by the public good argument.

Figure 4. Net stand alone costs (NC) of landscape preservation and food security



Look at figure 5. Observe that the IC curves start to rise at *FS* = 0.37 and *LP* = 1.33, respectively. For each public good, this is the level that follows as a by-product, without extra costs, of 1 unit of the other public good. It can be seen that the IC of elevating the level of landscape preservation when complete food security is assumed, is quite low. For example, only 0.6 billion NOK is required to raise the level of landscape preservation to the optimal level indicated in column 4 (*LP* = 1.49). This owes to the fact that preservation of agricultural land is a major component of both landscape preservation and food security. The IC is higher for food security, especially for high levels of food security ($\lambda > 1$), since food security requires more production and agricultural employment compared to the landscape preservation case.

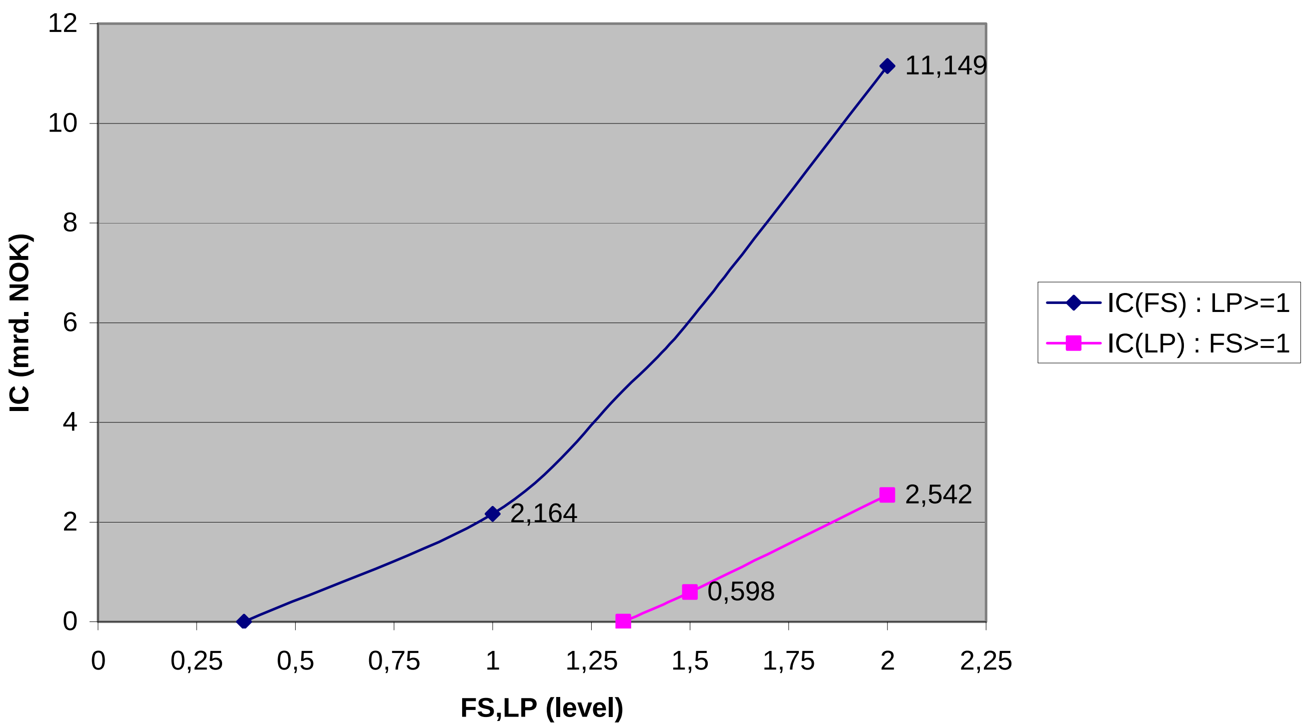
Naturally, the low incremental costs for landscape preservation are due to strong cost-complementarities, or economies of scope, between the public goods in question. An indicator on the degree of cost-complementarities was presented in equation (6). Below, this indicator is evaluated for the optimal solution in column 4:

$$c = 100\frac{NC(L^{M}=1)+NC(L^{LP}=1.49)-NC(L^{M}=1)-IC(L^{LP}=1.49)}{NC(L^{M}=1)+IC(L^{LP}=1.49)} = 100\frac{5.587-0.598}{5.449+0.598} = 82.5\%$$

Observe, that in this case the cost of joint production is: $NC(L^{M}=1)+IC(L^{LP}=1.49)$, while the sum of stand alone costs are: $NC(L^{M}=1)+NC(L^{LP}=1.49)$. The corresponding values can be found in figure 4 and 5.

As can be seen, the percentage extra costs of producing optimal levels of the two public goods separately compared to joint production, is more than 80%, which indicates that the cost complementarities are high.

Figure 5. Incremental costs



5. Concluding remarks

Without agricultural support, the levels of agricultural public goods will fall short of the demand in high cost countries like Norway, Finland, Iceland and Switzerland. However, as demonstrated in this paper using Norway as a case, the current support and agricultural activity is far out of proportions from a public goods perspective. The simulations show that at most 40% of the current support level can be defended by the public good argument. Furthermore, the present support, stimulating high production levels, is badly targeted at the public goods in question. Since agricultural land is a major component of both food security and landscape preservation, thus giving rise to a high degree of cost complementarities between the two public goods, it would be more efficient to support land extensive production techniques, than production *per se*. Naturally, production and trade will also be affected by support to sustain public goods, but, as illustrated by the simulations, to a far less extent.

Although, we believe the main conclusions are robust, it should be admitted that simulation results in this area are uncertain. In general, it is difficulty to specify and measure multidimensional public goods like landscape preservation and food security. Also, it is hard to reveal the corresponding willingness to pay for such goods. A main contribution of this paper has been to give a modeling approach to these problems.

Appendix

The model is a partial equilibrium model of the Norwegian agricultural sector. For given input costs and demand functions, market clearing prices and quantities are computed. Prices of goods produced outside the agricultural sector or abroad are taken as given. As the model assumes full mobility of labor and capital, it must be interpreted as a long run model. A technical description of an earlier version of the model is given in Brunstad et al. (1995b).

The model covers the most important products produced by the Norwegian agricultural sector, in all 14 final and 9 intermediary products. Most products in the model are aggregates. Primary inputs in the model are: land (four different grades), labor (family members and hired), capital (machinery, buildings, livestock) and other inputs (fertilisers, fuel, seeds, etc.). The prices of inputs are determined outside the model and treated as given.

Supply in the model is domestic production and imports. Domestic production takes place on the model's approximately 400 different "model farms". The farms are modeled with fixed input and output coefficients, based on data from extensive farm surveys carried out by the Norwegian Agricultural Economics Research Institute, a research body connected to the Norwegian Ministry of Agriculture. Imports take place at given world market prices inclusive of tariffs and transport costs. Domestic and foreign products are assumed to be perfect substitutes. The country is divided into nine production regions, each with limited supply of the different grades of land. This regional division allows for regional variation in climatic and topographic conditions and makes it possible to specify regional goals and policy instruments. The products from the model farms go through processing plants before they are offered on the market. The processing plants are partly modelled as pure cost mark-ups (meat, eggs and fruit), and partly as production processes of the same type as the model farms (milk and grains).

The domestic demand for final products is represented by linear demand functions. These demand functions are based on existing studies of demand elasticities, and are linearised to go through the observed price and quantity combination in the base year (1990). Between the meat products there are cross price effects, while cross price effects are neglected for all other products for which the model only assumes own price effects. The demand for intermediary products are derived from the demand for the final products for which they are inputs. Export take place at given world market prices.

Domestic demand for final products is divided among 5 separate demand regions, which have their own demand functions. Each demand region consists of one or several production regions. If products are transported from one region to another, transport costs are incurred. For imports and exports transport costs are incurred from the port of entry and to the port of shipment respectively. In principle restrictions can be placed on all variables in the model. The restrictions that we include, can be divided into two groups:

(1) Scarcity restrictions: upper limits for the endowment of land, for each grade of land in each region.

(2) Political restrictions: lower limits for land use and employment in each region, for groups of regions (central regions and remote areas), or for the country as a whole; maximum or minimum quantities for domestic production, imports or exports; maximum prices.

In the model, the economic surplus (consumer's surplus plus producer's surplus) of the agricultural sector is maximized. This maximization is performed subject to demand and supply relationships and the imposed restrictions. Which restrictions are included depends upon what kind of simulation that is attempted. The solution to the model is found as the prices and quantities that give equilibrium in each market. No restrictions must be violated, and no model farm or processing plant that is active, must be run at a loss.

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