Multifunctional Agriculture and the Preservation of Environmental Benefits

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1. Introduction

Agriculture is an economic activity which provides multiple benefits to society, ranging from the satisfaction of basic needs to the appreciation of rural amenities. Moreover, agricultural activities can have direct impacts on environmental functions, such as nutrient cycling, soil protection, flood control, and habitats for birds, insects and soil organisms. Some of these functions are crucial for sustainable agriculture, as they influence future soil productivity. Some provide non-use benefits to society (indirect use, option, existence and bequest values) in form of biodiversity and habitat protection as well as ecosystem and watershed functions. In addition, non-environmental benefits associated with agriculture comprise food safety and food security, rural employment and the socio-economic development of rural areas, and cultural heritage. Altogether, this constitutes the so-called *multifunctional character of agriculture*. It embraces a set of non-market costs and benefits, and thus constitutes a potential source of market failure. Correspondingly, the multifunctionality of agriculture could provide an efficiency-based argument for government support to farmers. Indeed, based on such considerations, the concept of multifunctionality emerged as an argument

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for including "non-trade concerns" in the negotiations of the World Trade Organization (WTO) on agriculture.

Originally propagated by the European Union, Norway, Switzerland, Japan and South Korea, the concept is prone to different interpretations. On the one hand, the ongoing debate about the multifunctionality of agriculture shows consensus about the existence of multiple benefits arising from agriculture to society (e.g., ABLER, 2001; OECD, 2001). On the other hand, there is disagreement as regards the justification of government intervention and the choice of adequate policy instruments (e.g., ANDERSON, 2000; BLANDFORD and BOISVERT, 2002; BOHMAN, COOPER, MULLARKEY, NORMILE, SKULLY, VOGEL and YOUNG, 1999; OECD, 2003; VATN, 2002). Nonetheless, the *concept of multifunctionality* has been adopted as a policy principle by OECD Agriculture Ministers in 1998, recognising that

> beyond its primary function of supplying food and fibre, agricultural activity can also shape the landscape, provide environmental benefits such as land conservation, the sustainable management of renewable natural resources and the preservation of biodiversity, and contribute to the socio-economic viability of many rural areas. (OECD, 2001, p. 5)

The entirety of these benefits can be referred to as the *total economic value* of agriculture. This goes along with the challenge of valuing the non-market outputs of agriculture and targeting the "right" prices down to the farm level in order to eliminate welfare losses and trade distortions (ABLER, 2001; RANDALL, 2003).

Yet, the total economic value of agriculture *per se* cannot justify government intervention, but it provides useful information for policy analysis. Indeed, the concept of total economic value constitutes the framework of a *positive* approach which allows us to analyse in a descriptive way the multiple benefits of agriculture in relation to agricultural production processes and outputs. It constitutes the basis for addressing various stakeholder concerns. In contrast, a *normative* approach would allow for policy judgements that are based on welfare economic theory. In this case, the analysis would shift towards the societal objectives associated with agriculture and the environment, and involve conditions for optimal allocation of land and other scarce resources among competing uses, the assignment of environmental property rights, as well as linkages between agricultural policies and international trade.

Building on existing literature, the aim of the present article is to investigate the welfare economic aspects of multifunctional agriculture for a small open economy, and to address the question to what extent welfare economic considerations can justify government intervention and support to farmers. To this end, the article provides an analytical framework for the evaluation of alternative policy measures to support farmers for generating environmental benefits. In Section 2, we present the analytical framework of a highly aggregated economic optimisation model which includes the allocation of land among forest, agriculture and urban uses, as well as positive and negative externalities. The related problem of optimal land allocation is analysed in Section 3 from a welfare economic perspective. This includes the joint consideration of positive and negative externalities, as well as efficiency and equity concerns, that are further elaborated in Section 4. Finally, Section 5 concludes.

2. Formalising the Debate – A Model of Optimal Land Allocation

The multifunctional character of agriculture is largely determined by the allocation of land and the joint production of land-related benefits. It involves the relationship between agricultural production and the preservation of agricultural land. The latter often yields significant amenity and ecological benefits that may not be reflected in the prevailing allocation of land between agricultural and non-agricultural uses. From an economic perspective, further government intervention may thus be justified because of the failure of the land market to fully consider these benefits from agriculture in allocating land (Gardner, 1977; Lopez, Shah and Altobello, 1994; Bromley, 2000). On the other hand, the question is about what the public gets from preserving farmland, and whether other land uses would yield greater social returns than agriculture (McConnell, 1989). This is a key issue in the debate on multifunctionality, which inevitably involves differences in perception and values associated to the rural landscape (Hodge, 1991; Mahé, 2001). On the consumers' side, it clearly involves an empirical question of environmental valuation (Randall, 2002; Lee, Paarlberg and Bredahl, 2005), while the principle issue on the production side of multifunctionality concerns the nature and degree of jointness in production, which requires that the multiple outputs be considered simultaneously (OECD, 2001; Vatn, 2002). These issues are most usefully integrated in the formal framework of an optimal allocation model with competing uses of land and other production factors.

Our analysis is based on the framework of a static allocation model of a small open economy which is endowed with two primary factors, homogenous land B and labour A, that are used to produce two commodities, an agricultural good Y_1 and a non-agricultural good Y_2. In addition, natural products Y_0 are harvested from sustainably managed forest land. Correspondingly, the total amount of land B is allocated to three uses: forest B_0 (wilderness or nature), agriculture B_1, and manufacturing B_2 (urban or industrial areas):

$$B_0 + B_1 + B_2 = B \tag{1}$$

The optimal allocation of the land requires that the social value marginal products of the different uses are equalised – i.e., the marginal benefits to society must be the same for each form of land use. Correspondingly, conditions for optimal land allocation must be determined from a societal or social planner's point of view. This cannot be restricted to the production values of the land.

Indirect use and non-use values must also be taken into account. To this end, we introduce the concept of environmental quality as a formal construction at the interface of the interdependent systems of economy and the environment. It conceptually integrates the different components of an ecosystem and allows us to address the economic valuation problem in the context of multifunctional agriculture. According to RANDALL (2002), this is complicated because, "in general, a valid total valuation cannot be obtained by independent piecewise valuation; that is, adding up the component values, each estimated independently". To solve this problem Randall proposes a valuation strategy which begins with a valuation of the multi-component green output of agriculture on a large (e.g., continental) scale, as an upper bound value to the sum of all the local and particular component values. Formally, this corresponds to our concept of environmental quality which shall integrate those environmental components that are relevant with respect to the multifunctional character of agriculture on an aggregate level: rural landscape and water quality.[1]

Correspondingly, we define environmental quality Q as a monotonically increasing and strictly concave function in both agricultural and forest land, B_1 and B_0, and rural water quality $W = W(E)$ which is impaired by pollution E from agricultural sources ($\partial W / \partial E < 0$):[2]

1 In a further step, one may look more detailed at the various components – like trees, hedges, field patterns and buffer strips – that influence the rural landscape and water quality. This is more usefully analysed at a local rather than national scale (HEDIGER, 2003a; LANKOSKI and OLLIKAINEN, 2003), and lies beyond the scope of this article.

2 For simplicity and to focus on the subject matter of this article, we abstract from other impacts upon environmental quality that arise, for example, through gaseous emissions (ammonia, nitrous oxide, methane) from agriculture, greenhouse gases and water pollution from industrial and urban sources, etc. We agree with one of the reviewers that such impacts are observed in reality and that the presence of negative externalities from non-agricultural production might strongly affect optimal land allocation (not necessarily real land use decisions) in favour of extensive agricultural production and land use. This could be shown with an extended and more complicated version of our stylised allocation model.

$$Q = Q(B_0, B_1, W(E)) \tag{2}$$

As an unintended side-effect, environmental pollution is caused by the use of chemical inputs that is purchased from other industries, and manure (animal waste) which is an intermediate product within the agricultural system and directly related to the aggregate net output from agriculture. It can be mitigated by the use of more labour intensive production methods. Consequently, aggregate emissions E are represented in our stylised model as a convex function which increases with chemical inputs Z_1 (fertilisers and pesticides) and net output Y_1 (serving as a proxy for animal waste), but decreases with labour input A_1. Altogether, this formulation allows us to integrate land use decisions, rural amenities and water quality:[3]

$$E = E(Z_1, Y_1, A_1) \tag{3}$$

with

$$Y_1 = Y_1(A_1, B_1, Z_1) \tag{4}$$

representing total agricultural production, which is concave and increasing with labour A_1, land B_1, and purchased inputs Z_1 (fertilisers and pesticides).[4]

In addition to these environmental aspects of agricultural land use and water pollution, we consider further issues in our model that are essential for determining conditions of optimal resource allocation and assessing social benefits of multifunctional agriculture. First, we assume that our economy imports additional agricultural products M_1 in exchange for manufactured goods X_2 at world market prices p_1 and p_2:

$$p_1 M_1 = p_2 X_2 \tag{5}$$

3 Our model is broader in conception than those of McConnell (1989) who only includes three types of land use but does not address pollution, Lopez, Shah and altobello (1994) that abstract from forest land and pollution, and Peterson, boisvert and de Gorter (2002) who jointly address rural amenity benefits and pollution, but restrict their analysis to agricultural land use.

4 Equations (3) and (4) give a simplified representation of the agricultural production system with one aggregate final output Y_1 that includes livestock and crop products. Intermediate outputs, such as forage and manure, that flow between livestock and land based production are implicit in this stylised formulation. On the one hand, forage production is implied in equation (4). On the other hand, the use of manure is considered through the inclusion of Y_1 in the emission function (3).

Hence, the final consumption of agricultural and manufactured goods, respectively, is

$$C_1 = Y_1 + M_1 \text{ and } C_2 = Y_2 - Z_1 - X_2 \tag{6}$$

whereas

$$Y_2 = Y_2(A_2, B_2) \tag{7}$$

Y_2 denotes the total output from manufacturing that is represented by an increasing and concave function in A_2 and B_2, the inputs of labour and land in manufacturing. Z_1 is the intermediate output which is used as production factor in agriculture.

Furthermore, sustainable management of forest resources on the area B_0 requires labour input A_0 and allows our economy to harvest Y_0 for domestic consumption (non-traded good). This is represented by the increasing and concave production function:

$$Y_0 = Y_0(A_0, B_0) \tag{8}$$

The total labour capacity A is allocated to forest management A_0, agricultural production A_1, and the production of manufactured goods and services A_2:

$$A_0 + A_1 + A_2 = A \tag{9}$$

Finally, the multifunctional character of agriculture depends on the valuation of the different outcomes by the individuals of a society. This is usefully expressed in terms of individual preferences, and represented by the utility function of a representative consumer: $u = u(y_0, c_1, c_2, Q)$ with $y_0 = Y_0/N$, $c_1 = C_1/N$ and $c_2 = C_2/N$ denoting per-capita consumption of forest products, agricultural products and manufactured goods, respectively, and Q representing environmental quality as defined in equation (2).

The individual utility function u is assumed to be monotonically increasing in each variable and strictly concave for any positive value of y_0, c_1, c_2 and Q. Assuming uniform preferences and equal endowment in our society, the social welfare function can be written in a simple utilitarian form which is proportional to the size of population N:

$$U = Nu(y_0, c_1, c_2, Q) \tag{10}$$

To determine the socially optimal allocation of land and other resources, we maximise this function subject to the production system and the economy-environment relationships given in equations (1) through (9). This is represented by the subsequent Lagrange function which is maximised with respect to all decision variables:

$$\begin{aligned} L = \; & Nu(y_0, c_1, c_2, Q) - \lambda_0[Ny_0 - Y_0(A_0, B_0)] \\ & -\lambda_1[Y_1 - Y_1(A_1, B_1, Z_1)] - \lambda_2[Y_2 - Y_2(A_2, B_2)] \\ & -\lambda_A[A_0 + A_1 + A_2 - A] - \lambda_B[B_0 + B_1 + B_2 - B] \\ & -\lambda_Q[Q - Q(B_0, B_1, W(E))] + \lambda_E[E - E(Z_1, Y_1, A_1)] \\ & -\mu[p_1(Nc_1 - Y_1) + p_2(Nc_2 - Y_2 + Z_1)] \end{aligned} \tag{11}$$

From the first-order optimality conditions for an interior solution, we get the subsequent equations for the shadow prices (Lagrange multipliers λ_0, λ_1, λ_2, λ_A, λ_B, λ_Q, $\lambda_E > 0$ and $\mu = 1$):[5]

$$\lambda_0 = \frac{\partial u}{\partial y_0} \tag{12}$$

$$\lambda_1 = p_1 - \lambda_E \frac{\partial E}{\partial Y_1} \text{ with } p_1 = \frac{\partial u}{\partial c_1} \tag{13}$$

$$\lambda_2 = p_2 = \frac{\partial u}{\partial c_2} = \lambda_1 \frac{\partial Y_1}{\partial Z_1} - \lambda_E \frac{\partial E}{\partial Z_1} \tag{14}$$

$$\lambda_A = \lambda_0 \frac{\partial Y_0}{\partial A_0} = \lambda_1 \frac{\partial Y_1}{\partial A_1} - \lambda_E \frac{\partial E}{\partial A_1} = \lambda_2 \frac{\partial Y_2}{\partial A_2} \tag{15}$$

$$\lambda_B = \lambda_0 \frac{\partial Y_0}{\partial B_0} + \lambda_Q \frac{\partial Q}{\partial B_0} = \lambda_1 \frac{\partial Y_1}{\partial B_1} + \lambda_Q \frac{\partial Q}{\partial B_1} = \lambda_2 \frac{\partial Y_2}{\partial B_2} \tag{16}$$

$$\lambda_E = -\lambda_Q \frac{\partial Q}{\partial W} \frac{\partial W}{\partial E} \tag{17}$$

$$\lambda_Q = N \frac{\partial u}{\partial Q} \tag{18}$$

5 From combining the first-order conditions $\partial L / \partial c_i = 0$ (with $i = 1,2$) and the standard neoclassical requirement of equalising prices and marginal utilities of private goods, $p_i = \partial u / \partial c_i$, we get $\mu = 1$.

These equations determine the efficiency prices of the three commodities and the two production factors considered, as well as those of pollution and environmental quality, respectively. They build the formal basis for the subsequent analysis of optimal land allocation and provision of environmental amenities from agriculture and forest land, and are accordingly interpreted in the following section.

3. Optimal Land Allocation in the Presence of Environmental Externalities

3.1 Rural Amenities Are External Benefits

The condition for a socially optimal allocation of land among forest, agricultural and urban uses is given in equation (16). It requires that the shadow price of the land, λ_B, equalises the social value marginal product of the land among all uses. Moreover, it illustrates the relevance of the concept of total economic value. For both agricultural and forest land, the shadow price (rental value of the land) includes two components: the value of land use in production, $\lambda_i \cdot \partial Y_i / \partial B_i$, and the indirect use and non-use values of the land, $\lambda_Q \cdot \partial Q / \partial B_i$ (with $i = 0,1$). Under consideration of equations (17) and (18), the second term reveals the public good characteristics of the environment: non-excludability and undepletability. This signifies that the appreciation of rural amenity benefits does not foreclose others from doing the same, and that enjoying the rural landscape does not impair the quality of the environment.

Despite these public good characteristics, environmental quality may not usefully be regarded as a public good which is produced by agriculture or forestry. Rather, these primary industries use land as a production factor and cultivate the natural environment for the purpose of enhancing the flow of food and fibre from their land. The rural landscape is then the consequence of land use patterns. It gains its value from its scale and the relationship between the different components of the landscape (HODGE, 1991). In general, this value is not reflected in market prices. Rather, the societal value of agricultural and forest land includes real interdependencies between production and individual utility functions that are not reflected in the land market. These production-related impacts on the environment and on individual utilities exhibit the character of an "undepletable" positive externality in the sense of BAUMOL and OATES (1988). This is formally represented in the subsequent equation, which results from substituting the relevant optimality conditions in equation (16):

$$\lambda_B = \frac{\partial u}{\partial y_0}\frac{\partial Y_0}{\partial B_0} + N\frac{\partial u}{\partial Q}\frac{\partial Q}{\partial B_0}$$
$$= \left(p_1 + N\frac{\partial u}{\partial Q}\frac{\partial Q}{\partial W}\frac{\partial W}{\partial E}\frac{\partial E}{\partial Y_1}\right)\frac{\partial Y_1}{\partial B_1} + N\frac{\partial u}{\partial Q}\frac{\partial Q}{\partial B_1}$$
$$= p_2\frac{\partial Y_2}{\partial B_2} \tag{19}$$

It shows that, apart of the production value, both forest and agricultural land include an additional value which can be enjoyed by all members of society without being depleted. For an optimal resource allocation the external benefits of agricultural and forest land use must be internalised. To this end, managers of agricultural and forest land may receive a compensation payment per land unit according to the social marginal external benefit of the land.

According to equation (19), these payments must be equal to

$$N\cdot(\partial u/\partial Q)\cdot(\partial Q/\partial B_1) \text{ and } N\cdot(\partial u/\partial Q)\cdot(\partial Q/\partial B_0)$$

per unit of agricultural and forest land, respectively. Without such payments, too much land would be allocated to urban uses, and the provision of rural environment benefits would be below the socially optimal level. In contrast, with adequate payments, the production-related rental value of farmland could be below the rental price of urban land, and it would still be profitable to the farmers to cultivate the land. From a social point of view this is optimal as long as the difference between the private rental prices for urban and agricultural uses is less than the marginal external benefit of the agricultural land.

3.2 Negative Agricultural Externalities

Yet, agriculture does not only generate positive side effects. Negative externalities due to water pollution, caused by the application of manure, chemical fertilisers and pesticides, have become major policy issues in many countries (cf. Shortle and Abler, 2001). This is formally included in our stylised model with the aggregate emission function $E = E(Z_1, Y_1, A_1)$, and reflected in the first-order optimality conditions regarding the social net marginal benefit of agricultural production, Y_1, the social value marginal product of artificial inputs, Z_1, and agricultural labour, A_1, respectively. Thus, by substituting equations (15) and (16) into conditions (11) through (13), we get:[6]

$$\lambda_1 = p_1 - \lambda_E \frac{\partial E}{\partial Y_1} = p_1 + N \frac{\partial u}{\partial Q} \frac{\partial Q}{\partial W} \frac{\partial W}{\partial E} \frac{\partial E}{\partial Y_1} < p_1 \tag{20}$$

$$\begin{aligned} \lambda_2 &= p_2 \\ &= \lambda_1 \frac{\partial Y_1}{\partial Z_1} - \lambda_E \frac{\partial E}{\partial Z_1} \\ &= p_1 \frac{\partial Y_1}{\partial Z_1} + N \frac{\partial u}{\partial Q} \frac{\partial Q}{\partial W} \frac{\partial W}{\partial E} \left(\frac{\partial E}{\partial Z_1} + \frac{\partial E}{\partial Y_1} \frac{\partial Y_1}{\partial Z_1} \right) \\ &< p_1 \frac{\partial Y_1}{\partial Z_1} \end{aligned} \tag{21}$$

$$\begin{aligned} \lambda_A &= \lambda_1 \frac{\partial Y_1}{\partial A_1} - \lambda_E \frac{\partial E}{\partial A_1} \\ &= p_1 \frac{\partial Y_1}{\partial A_1} + N \frac{\partial u}{\partial Q} \frac{\partial Q}{\partial W} \frac{\partial W}{\partial E} \frac{\partial E}{\partial A_1} \\ &> p_1 \frac{\partial Y_1}{\partial Z_1} \end{aligned} \tag{22}$$

Given the fact that pollution is an "undepletable" negative externality which can affect the utility of each individual without reducing the influence on the utility of any other person (BAUMOL and OATES, 1988), the optimal price of the agricultural commodity must be above the private marginal cost of production, as shown in equation (20). Likewise, equations (21) and (22) indicate that the optimal price of artificial inputs in agricultural production must be above the private value marginal product of these factors and that agricultural labour must be compensated according to its total marginal value product in production and pollution abatement. Altogether, this requires a correction of market prices – the internalisation of external costs –, which can be realised as follows:

6 Remember that $\partial W / \partial E < 0$ and $\partial E / \partial A_1 < 0$.

a) According to equation (20), consumers have to pay an extra price equal to the marginal external cost $\lambda_E(\partial E/\partial Y_1)$ of the final product, such that $p_1 = \lambda_1 + \lambda_E \cdot (\partial E/\partial Y_1)$.
b) Farmers must be given adequate incentives to internalise the external cost of agricultural production and input use, as shown in equations (21) and (22).

These measures are consistent with the "polluters pay principle". They have the effect of reducing the level of agricultural production and pollution to the socially optimal levels. At the same time, both measures cause a reduction of the direct use value of agricultural land, $\lambda_1 \cdot \partial Y_1/\partial B_1$, and the optimal amount of land in agriculture. Moreover, the internalisation of external costs has adverse effects on the farmers' net revenues, and thus affects the income distribution in society.

The resulting trade-off between efficiency and equity concerns could in principal be resolved by providing subsidies to farmers for reducing negative externalities and improving the rural water quality. Such a policy would allow farmers to remain on income levels comparable to the situation without internalising external costs. Yet, it would correspond to the "victims pay principle", and imply a different assignment of environmental property rights than the solution discussed before. In addition, subsidies to farmers for improving water quality would have an effect on the allocation of land. This can formally be proven as follows.

Charging farmers a pollution fee τ equal to the marginal external cost of agricultural production ($\tau = \lambda_E \cdot \partial E/\partial Y_1 > 0$), or giving them a subsidy σ equal to their marginal abatement cost ($\sigma > 0$) does not have the same effect on the net marginal value of agricultural production

$$\lambda_1(\tau) = p_1 - \tau < p_1 + \sigma = \lambda_1(\sigma) \tag{23}$$

and thus on the rental price of agricultural land:

$$\lambda_B(\tau) = \lambda_1(\tau)\frac{\partial Y_1}{\partial B_1} + N\frac{\partial u}{\partial Q}\frac{\partial Q}{\partial B_1} < \lambda_1(\sigma)\frac{\partial Y_1}{\partial B_1} + N\frac{\partial u}{\partial Q}\frac{\partial Q}{\partial B_1} = \lambda_B(\sigma) \tag{24}$$

A substitution of (23) in the first-order condition (13) reveals that, in an open economy with given world market prices, the rental value of the agricultural land with subsidy for pollution abatement, $\lambda_B(\sigma)$, would be larger than the value of agricultural land in case of a pollution fee, $\lambda_B(\tau)$, which is equal to the efficiency price of the land given in equation (19). As a consequence, the provision of subsidies for pollution abatement would tend to increase the demand for agricultural land above the socially optimal amount.

The related loss of social welfare could be justified at a national level by equity considerations. However, as any form of subsidies for variable input factors and outputs of production, payments for pollution abatement are a potential source of market distortion. This reveals the fundamental trade-off between concerns of efficiency and equity, which could be overcome by earmarking at least some of the effluent charge revenue for environmental projects (JIANG, 2001).

4. A Mixed Approach to Improve Water Quality and the Rural Landscape

In the present context of agricultural water pollution and landscape amenities, the idea of earmarking effluent charge revenues could be translated in a lump-sum reimbursement to the farmers. This however may reduce their incentive to select cost-effective measures of pollution control. As an alternative, HEDIGER (2003a, 2003b) proposes a budget-balancing charge-subsidy scheme as a mixed instrument for pollution control and sustainable resource management at the local level, and as conceptual basis for a voluntary environmental agreement between farmers and the government. The latter is the equilibrium outcome of negotiations between the two parties (SEGERSON and MICELI, 1998). It involves agreement upon an ambient quality standard that is binding to the signatories of the contract, and requires regulatory threats and reliable monitoring to involve sufficient participation (ALBERINI and SEGERSON, 2002).

In general, the establishment of an ambient (water) quality standard results in a shift to a *second-best* framework. This can be justified by the information requirement for optimal policies (BAUMOL and OATES, 1988) and the non-point-source characteristics of agricultural water pollution (SHORTLE and ABLER, 2001). In the later case, individual emissions usually cannot be monitored and measured at acceptable cost. In this situation, emission-based instruments such as taxing or regulating the individual discharge at the source are not a viable option. Instead, environmental economists proposed second-best instruments to correct market failures due to nonpoint-source pollution (GRIFFIN and BROMLEY, 1982; SEGERSON, 1988; CABE and HERRIGES, 1992; XEPAPADEAS, 1995). With respect to agricultural water pollution, this involves the requirement of politically determined water quality targets that must be achieved at least cost in each watershed. Moreover, it involves a normative shift which gives farmers the right to pollute the environment up to the maximum of the applicable ambient standard.

With respect to our allocation model and formal analysis, this shift also implies some minor changes. The optimal levels of economic activity, factor allocation and environmental quality do not necessarily correspond to the first-best solution. Rather, they are conditionally optimal and depend on the fixed water quality standard. As a consequence, the shadow price of pollution does no longer equalise the marginal damage cost. Instead, it measures the sensitivity of the objective function (social welfare) to marginal changes in the water quality standard (environmental constraint).

Building on this background, we present the idea of a *charge-subsidy scheme* as an analytical framework which allows us to jointly address concerns of efficiency and equity, and at the same time provides a benchmark for the evaluation of adequate policy measures. It is conceptually based on a charge (environmental tax) levied on polluters according to the shadow price of pollution, and a reimbursement of the tax revenue to farmers as compensation for *"land retirement"*, that is, for converting cropland and intensive pastures into extensive grassland or buffer strips on which no fertilisers are applied. This land is retired in the sense that yield from extensive grassland and buffer strips can be used as an intermediary input (forage or compost, F_1^0) in the agricultural production process, rather than as final agricultural product.[7] Correspondingly, the aggregate production function must be split into two parts, which are assumed to be strictly concave and monotonically increasing with regard to the corresponding production factors:

$$Y_1 = Y_1(A_1^1, B_1^1, F_1^0, Z_1) \text{ and } F_1^0 = F_1^0(A_1^0, B_1^0) \tag{25}$$

with B_1^1 and B_1^0 denoting the areas of agricultural land $(B_1^1 + B_1^0 = B_1)$ that is dedicated to intensive and extensive uses, respectively. Moreover, A_1^1 and A_1^0 denote the labour inputs $(A_1^1 + A_1^0 = A_1)$ that are devoted to producing the final agricultural output Y_1 and the additional intermediate output F_1^0, respectively.

With regard to the landscape and amenity benefits resulting from land use in agriculture, we may distinguish two cases. In the first one, we simply assume that land retirement does not generate any additional landscape benefits, such that the environmental quality function remains the same as in equation (2): $Q = Q(B_0, B_1, W(E))$ with $B_1 = B_1^1 + B_1^0$. In this case, farmers should, according to equation (19), receive a payment ψ to internalise the marginal external benefits of agricultural land:

7 The land which is 'retired' in this sense is not converted into forest or wilderness, but devoted to extensive agricultural uses.

$$\psi = N \frac{\partial u}{\partial Q} \frac{\partial Q}{\partial B_1} > 0 \tag{26}$$

On the contrary, if extensive grassland and buffer strips generate additional benefits to society – like more diverse landscapes and improved habitats and biodiversity –, then the environmental quality function must be extended to $Q = Q(B_0, B_1, B_1^0, W(E))$ and farmers should receive an extra payment to internalise the additional value of this part of agricultural land:

$$\xi = N \frac{\partial u}{\partial Q} \frac{\partial Q}{\partial B_1^0} \geq 0 \tag{27}$$

In the first case, this value can simply be set equal zero (i.e. $\xi = 0$), whereas in the second case a differentiated payment for internalising social amenity benefits of the landscape would be justified.

Formally, the above extensions can be integrated in the following Lagrangean for the aggregate agricultural sector:[8]

$$\begin{aligned} \tilde{L}_1 = \ & p_1 Y_1 - p_A[A_1^1 + A_1^0] - p_B[B_1^1 + B_1^0] - p_2 Z_1 \\ & + \psi[B_1^1 + B_1^0] + \xi B_1^0 - \tau E(Y_1, Z_1, A_1^1) + \sigma B_1^0 \\ & - \tilde{\lambda}_1[Y_1 - Y_1(A_1^1, B_1^1, F_1^0, Z_1)] - \lambda_1^0[F_1^0 - F_1^0(A_1^0, B_1^0)] \quad \text{max!} \end{aligned} \tag{28}$$

with p_1 and p_2 denoting the commodity prices, p_A and p_B the socially optimal factor prices for labour and land, such as given by λ_A and λ_B in equations (15) and (16). Moreover, τ represents the effluent charge that is required to satisfy the ambient target $\hat{E}_{\S}$:

$$E(Y_1, Z_1, A_1^1) \leq \hat{E}_{\S} \tag{29}$$

In addition, σ is the rate of subsidy that is granted for retiring the share x of agricultural land B_1, which must satisfy the subsequent equality to balance the budget of the charge-subsidy scheme ($0 \leq x \leq 1$):[9]

8 Notice that in the following we focus on the agricultural sector only, rather than the entire allocation problem as in Section 2. This simplification allows us to concentrate our analysis on the essential aspects of the proposed charge-subsidy scheme.

$$\sigma x B_1 = \tau E(Y_1, Z_1, A_1^1) \text{ with } xB_1 = B_1^0 \tag{30}$$

The remaining variables are the same as in our original model of Section 2.

This modified optimisation problem for the agricultural sector requires an iterative approach with simultaneous solution of equations (26) to (30). This implies that the rate of subsidy σ and the share of retired agricultural land x must be simultaneously determined with the effluent charge τ, the marginal external benefits of agricultural land ψ and ξ, as well as the solution of the second-best agricultural allocation problem (28) with the predetermined ambient water quality target (29). From the first-order conditions of this optimisation problem, we get the following marginal conditions for agricultural production:

$$\tilde{\lambda}_1 = p_1 - \tau \frac{\partial E}{\partial Y_1}, \; \lambda_1^0 = \tilde{\lambda}_1 \frac{\partial Y_1}{\partial F_1^0} \tag{31}$$

$$p_A = \tilde{\lambda}_1 \frac{\partial Y_1}{\partial A_1^1} - \tau \frac{\partial E}{\partial A_1^1} = \lambda_1^0 \frac{\partial F_1^0}{\partial A_1^0}, \; p_2 = \tilde{\lambda}_1 \frac{\partial Y_1}{\partial Z_1} - \tau \frac{\partial E}{\partial Z_1} \tag{32}$$

$$p_B = \tilde{\lambda}_1 \frac{\partial Y_1}{\partial B_1^1} + \psi = \lambda_1^0 \frac{\partial F_1^0}{\partial B_1^0} + \psi + \xi + \sigma \tag{33}$$

These conditions show that, to achieve the given water quality standard at the least cost, all production factors (labour, land, and intermediate inputs) must be compensated according to their marginal social value products, and that the latter must be equalised across the different production systems which are characterised in our model by intensive and extensive land use, respectively.

Moreover, equation (33) reveals the influence of the proposed charge-subsidy scheme upon the allocation of agricultural land. It particularly shows that the earmarking of the pollution charge revenue ($\sigma < 0$) increases the relative marginal

9 For simplicity, we assume in our formal representation an effluent charge imposed on emissions. Yet, in praxis this might not be feasible due to the nonpoint-source characteristics of rural water pollution. A practical alternative, as proposed by GRIFFIN and BROMLEY (1982), is to individually charge every input factor on which the generation of nonpoint-source pollution depends. In our model, this would require a system of taxes on agricultural land use as well as labour and fertiliser inputs, which must be designed such as to result in the same allocation of land and factor intensities as an emission charge theoretically would induce (HEDIGER, 2003a).

value of extensive agricultural land and, thus, gives an incentive to the farmers to reduce the area of intensively used cropland and grassland. At the same time, the rental price of the land p_B tends to increase, which – considering the standard assumption of declining marginal factor productivity – theoretically goes along with a decline in non-agricultural land uses. This effect, however, is counterbalanced by a decline of the marginal social benefits of agricultural land, ψ and ξ, which follows from the assumed concavity of the environmental quality function. Hence, one can expect that the net effect of the charge-subsidy scheme upon the overall land use might be more or less neutral.[10]

The major allocation effect of mixed incentive scheme takes place within the agricultural sector, and is characterised by the above mentioned shift from intensive to extensive land uses. Compared to a policy without land retirement but with the same aggregate emission target $\hat{E}_{\S}$, the proposed scheme particularly reduces the pressure on emission reduction which is required from the remaining cropland and intensive pastures. At the same time, the optimal intensity of cultivation is higher on the remaining land of production than without the subsidy for land retirement (HEDIGER, 2003b). This is due to the reduced land area with polluting activities. In other words, the rates of fertiliser application must not uniformly be reduced on all agricultural land. Rather, if some plots are "retired" the permissible pollution load from each of the remaining plots of intensive pasture and cropland is higher than without land retirement while respecting the overall emission target $\hat{E}_{\S}$.[11]

Given the fact that the use of an aggregate emission target implies a second-best policy with an altered assignment of environmental property rights, the resulting allocation of land and labour must not correspond to the first-best solution of our original model in Section 2. This is related to the foundations of welfare economics (JUST, HUETH and SCHMITZ, 2004), saying that efficiency can be defined only with reference to a given distribution of income and property rights, and that, if one changes income distribution, one also changes the optimal factor allocation and product mix. Correspondingly, we cannot simply

10 The effective impact of the charge-subsidy scheme upon the allocation of land and other production factors, however, depends on the concrete shape of the different functions and finally remains an empirical question.

11 Notice that this argumentation implies a differentiation of plots according to their site-specific productivity. As shown by HEDIGER (2003b) with an activity-analytic approach, there should be no retirement of cropland if the land rent of the plot exceeds the rate of subsidy. In contrast, intensive cultivation should be abandoned if the site-specific land rent falls below the rate of subsidy that is granted for land retirement.

compare the outcomes of the two models from an efficiency point of view. But, we can conclude that, in contrast to a pure subsidy for pollution abatement (cf. Section 3.2), the charge-subsidy scheme does not generate additional trade distortions, since the conditions of an efficient factor allocation and product mix of this second-best policy are satisfied.

Moreover, we can evaluate the proposed policy scheme from an equity point of view. This shows that the farmers' aggregate income does not decline by the amount of the effluent charge, since the latter is earmarked for land retirement. At the same time, tax payers must not bear the burden of subsidising land retirement. Thus, the charge-subsidy scheme integrates the requirements of efficiency (cost-effectiveness) and equity considerations. In contrast, to a pure pollution abatement subsidy, the charge-subsidy scheme is compatible with the conditions for an optimal land allocation and with payments to land managers according to the external benefits of agricultural and forest land. Given the usual nonpoint-source characteristic of rural water pollution, this conceptual scheme must be translated into a more operational approach. As propagated by GRIFFIN and BROMLEY (1982), this could be established with a system of charges imposed on all polluting inputs, which must then be combined with an earmarking of the related "effluent charge" revenue for "land retirement". Moreover, policy instruments that are conceptually based on the proposed scheme imply the assignment of environmental property rights to both farmers and consumers. This means that farmers keep the property rights on the land and landscape benefits. In contrast, the consumers have the implicit rights on clean air and water.

Altogether, if the goal of multifunctional agriculture is to attain a social optimum, it requires internalisation of the external costs. This implies a deviation from the private optimum. The adequate form of intervention cannot be decided without taking into consideration the other aspects of multifunctionality, namely the amenity values associated with agricultural land use and the assignment of environmental property rights. A balanced charge-subsidy scheme and voluntary environmental agreements between farmers and the government can in principle help to jointly address issues of efficiency, sustainability and equity. This allows us to theoretically determine the optimal allocation of land in the presence of environmental externalities, and to design adequate policy instruments. Yet, the optimal outcome may be different from the current situation, and a related policy change may have drastic consequences for farmers, compared to the status quo.

5. Conclusion

Agriculture inevitably interacts in major ways with the natural environment. Negative consequences are the loss of habitats, impairment of ecosystem functions, and agricultural water pollution. Positive aspects involve the effects on the rural landscape, which in many places is valued for its amenity benefits and cultural heritage. As a consequence of past human activity, it has largely been determined by the objectives of agricultural and environmental policies and influenced by developments on the world markets. Now, some OECD member countries are concerned about the consequences of trade liberalisation upon the multiple benefits from their agricultural systems. They are particularly concerned about the effects on the rural landscape from further reducing domestic agricultural support and border protection.

Indeed, the reduction of agricultural price and production support as well as the internalisation of external costs and benefits may not only result in a decrease of the net marginal value of agricultural products and the farmers' net revenues, but also in a decline of the agricultural land area and a change in the mix of farm products. On the one hand, this gives rise to concerns about the farmers' income and national food security, as well as modifications of the rural landscape. On the other hand, it brings about social welfare gains through the reduction of trade distortions and the elimination of related welfare losses. These benefits could, in principle, be used to partly compensate farmers for the non-desired distribution and food security effects. However, this must be decided on a political platform.

Furthermore, the elimination of market distortions may generate positive side-effects to society. The change in the product mix may also result in an improvement of the rural landscape and water quality, and thus lead to an increase of marginal external benefits and a decline of marginal external costs. In particular, the elimination of trade distortions and internalisation of externalities may induce a correction of the negative impacts of intensive agriculture (chemical use, waste disposal, and the removal of wildlife habitat and landscape features) that have "led to a perceived reduction in the quality of the rural environment and have reduced the values of other uses of the countryside" (HODGE, 1991).

To investigate this issue from a welfare economic perspective, we developed a formal approach which is more comprehensive and coherent with regard to environmental concerns than most of existing literature on multifunctionality. It particularly allows us to provide insights and recommendations for agri-environmental policy and multifunctional agriculture that are theoretically sound and consistent. Apart of providing the conditions for an optimal resource allocation, our analysis reveals that the environmental aspects associated with the multifunctionality of agriculture exhibit the character of undepletable externalities, as defined by Baumol and Oates (1988). This is fundamental for the analysis, and emphasises the need for internalising environmental externalities of agriculture. Moreover, it indicates that rural environmental benefits must not be separately produced as non-joint public goods (cf. Vatn, 2002). Rather, policy should first provide incentives to eliminate the various sources of market failure. To this end, an adequate mix of policy instruments is required.

On the one hand, farmers and forest managers should receive payments according to the marginal external benefits from the land. On the other hand, they should be charged for the marginal external costs of water pollution which is caused by the application of animal waste and chemical inputs. Apparently, this is complicated by the nonpoint-source characteristic of agricultural water pollution,[12] and the effects on income distribution of such policy.

From a perspective of cost effectiveness, the reduction of agricultural water pollution will, among other measures, require a partial retirement of cropland and conversion into extensive grassland and forest land and the installation of buffer strips, at least on marginal land and in areas with particularly valuable water resources (Ribaudo, Osborn and Konyar, 1994; Lankoski and Ollikainen, 2003; Hediger, 2003a, 2003b). In addition, the internalisation of external benefits can be expected to give an incentive to farmers to change land use patterns and provide a more diverse rural landscape with valuable elements such as trees, hedges, natural pastures and water courses. Altogether, we can reasonably expect that the internalisation of external costs and benefits will have a positive effect on the rural environment and agricultural income.

To alleviate the negative income effects, we propose a charge-subsidy scheme with the reimbursement of "effluent charge" revenues to the farmers for the retirement of cropland and intensive grassland. This leaves the property right on the land and landscape benefits with the farmers, and assigns the right on clean air and water to the consumers. In contrast to a subsidy for pollution abatement, the charge-subsidy scheme is consistent with the requirements of an optimal land allocation and would not cause new distortions on commodity and factor markets.

12 A detailed analysis of this issue is beyond the scope of this article, and has extensively been addressed in the literature. Shortle and Abler (2001) provide an actual and comprehensive review on this topic.

From a welfare economic perspective, the key issues of multifunctional agriculture are the realisation of social welfare gains due to the elimination of trade distortions and the internalisation of external costs and benefits, and the joint consideration of efficiency and equity concerns. The latter is crucial to minimise the burden of agricultural policy reform that would primarily be caused by a reassignment of environmental property rights. This further implies a theory-based argument for shifting the ongoing policy debate on the roles of agriculture in society – its multifunctionality – away from purely ideological grounds to a sound economic foundation that jointly addresses efficiency and equity issues and aims at eliminating distortionary effects arising from both positive and negative externalities.

References

ABLER, DAVID (2001), "A Synthesis of Country Reports on Jointness Between Commodity and Non-commodity Outputs in OECD Agriculture", Workshop on Multifunctionality, Paris, 2–3 July, 2001, Organisation for Economic Co-operation and Development, Directorate for Food, Agriculture and Fisheries.

ALBERINI, ANNA and KATHLEEN SEGERSON (2002), "Assessing Voluntary Programs to Improve Environmental Quality", *Environmental and Resource Economics*, 22, pp. 157–184.

ANDERSON, KYM (2000), "Agriculture's 'Multifunctionality' and the WTO", *Australian Journal of Agricultural and Resource Economics*, 44, pp. 475–494.

BAUMOL, WILLIAM J. and WALLACE E. OATES (1988), *The Theory of Environmental Policy*, Second edition, Cambridge, New York and Melbourne.

BLANDFORD, DAVID and RICHARD N. BOISVERT, (2002), "Multifunctional Agriculture and Domestic / International Policy Choice", *Estey Centre Journal of International Law and Trade Policy*, 3, pp. 106–118.

BOHMAN, MARY, JOSEPH COOPER, DANIEL MULLARKEY, MARY ANNE NORMILE, DAVID SKULLY, STEVEN VOGEL and C. EDWARD YOUNG (1999), "The Use and Abuse of Multifunctionality", Economic Research Service, USDA, Washington, DC.

BROMLEY, DANIEL W. (2000), "Can Agriculture Become an Environmental Asset?", *World Economics*, 1, pp. 127–139.

CABE, RICHARD and JOSEPH A. HERRIGES (1992), "The Regulation of Non-Point-Source Pollution Under Imperfect and Asymmetric Information", *Journal of Environmental Economics and Management*, 22, pp. 134–146.

Gardner, B. Delworth (1977), "The Economics of Agricultural Land Preservation", *American Journal of Agricultural Economics*, 59, pp. 1027–1036.

Griffin, Ronald C. and Daniel W. Bromley (1982), "Agricultural Runoff as a Nonpoint Externality", *American Journal of Agricultural Economics*, 64, pp. 547–552.

Hediger, Werner (2003a), "Alternative Policy Measures and Farmers' Participation to Improve Rural Landscapes and Water Quality: A Conceptual Framework", *Swiss Journal of Economics and Statistics*, 139, pp. 333–350.

Hediger, Werner (2003b), "Sustainable Farm Income in the Presence of Soil Erosion: An Agricultural Hartwick Rule", *Ecological Economics*, 45, pp. 221–236.

Hodge, Ian (1991), "The Provision of Public Goods in the Countryside: How Should It Be Arranged?", in: Nick Hanley (Ed.), *Farming and the Countryside: An Economic Analysis of External Costs and Benefits*, Wallingford, U.K., pp. 179–196.

Jiang, Tingsong (2001), "Earmarking of Pollution Charges and the Sub-Optimality of the Pigouvian Tax", *Australian Journal of Agricultural and Resource Economics*, 45, pp. 623–640.

Just, Richard E., Darell L. Hueth and Andrew Schmitz (2004), *The Welfare Economics of Public Policy: A Practical Approach to Project and Policy Evaluation*, Cheltenham, UK, and Northampton, MA, USA.

Lankoski, Jussi and Makku Ollikainen (2003), "Agri-Environmental Externalities: A Framework for Designing Targeted Policies", *European Review of Agricultural Economics*, 30, pp. 51–75.

Lee, John G., Philip L. Paarlberg and Maury Bredahl (2005), "Implementing Multifunctionality", *International Journal of Agricultural Resources, Governance and Ecology*, 4, pp. 216–231.

Lopez, Rigoberto A., Farhed A. Shah and Marilyn A. Altobello (1994), "Amenity Benefits and the Optimal Allocation of Land", *Land Economics*, 70, pp. 53–62.

Mahé, Louis-Pascal (2001), "Can the European Model be Negotiable in the WTO?", *EuroChoices,* Spring 2001, pp. 10–16.

McConnell, Kenneth E. (1989), "Optimal Quantity of Land in Agriculture", *Northeastern Journal of Agricultural and Resource Economics*, 18, pp. 63–72.

OECD (2001), *Multifunctionality: Towards an Analytical Framework*, Organisation for Economic Co-operation and Development, Paris.

OECD (2003), *Multifunctionality: The Policy Implications*, Organisation for Economic Co-operation and Development, Paris.

PETERSON, JEFFREY M., RICHARD N. BOISVERT and HARRY DE GORTER (2002), "Environmental Policies for a Multifunctional Agricultural Sector in Open Economies", *European Review of Agricultural Economics*, 29, pp. 423–443.
RANDALL, ALAN (2002), "Valuing the Outputs Of Multifunctional Agriculture", *European Review of Agricultural Economics*, 29, pp. 289–307.
RIBAUDO, MARC O., C. TIM OSBORN and KAZIM KONYAR (1994), "Land Retirement for Reducing Agricultural Nonpoint Source Pollution", *Land Economics*, 70, pp. 77–87.
SEGERSON, KATHLEEN (1988), "Incentives and Uncertainty for Nonpoint Pollution Control", *Journal of Environmental Economics and Management*, 15, pp. 87–98.
SEGERSON, KATHLEEN and THOMAS J. MICELI (1998), "Voluntary Environmental Agreements: Good or Bad News for Environmental Protection?", *Journal of Environmental Economics and Management*, 36, pp. 109–130.
SHORTLE, JAMES S. and DAVID G. ABLER, D.G., Eds. (2001), *Environmental Policies for Agricultural Pollution Control*, Wallingford, UK, and New York, USA.
VATN, ARILD (2002), "Multifunctional Agriculture: Some Consequences for International Trade Regimes", *European Review of Agricultural Economics*, 29, pp. 309–327.
XEPAPADEAS, ANASTASIOS P. (1995), "Observability and Choice of Instrument Mix in the Control of Externalities", *Journal of Public Economics*, 56, pp. 485–498.

SUMMARY

We investigate environmental aspects of agriculture from a welfare economic perspective and show that efficiency prices of agricultural and forest land include important amenity and non-use values that exhibit the character of undepletable externalities. To achieve a social optimum these must be internalised, while taking equity concerns into account. We propose compensation of farmers and forest managers according to the marginal external benefit of their land use and a combination of charges and subsidies to improve rural water quality. This is consistent with efficiency requirements and would not cause additional market distortions. Moreover, it would leave the property rights on the land with the farmers and assign the right on clean air and water to the consumers.