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# Welfare economics of conventional vs. alternative agriculture

## Zur Wohlfahrtsökonomie konventioneller vs. alternativer Landwirtschaft

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### Abstract

We develop a agricultural model assuming that conventional production is causing environmental externalities while more benign alternative production methods generate non-market amenity benefits and obtain a price premium in the marketplace. We analyze policies targeting external benefits and costs to capture interaction effects: polluting input taxes reduce the returns and subsidies needed to induce more benign production. Thus, it is only optimal to subsidize if the additional marginal amenity benefit exceeds the marginal external cost reductions due to the input tax. Terms of trade effects imply that large (land abundant) exporters have strategic incentives to overvalue external costs while large (land scarce) importers have strategic incentives to overrate non-market benefits. The model may serve to explain principal negotiating positions of major players within the WTO agriculture-environment sphere.

### Key words

agriculture, environment, trade, welfare economics

### Zusammenfassung

Wir erstellen ein Modell unter der Annahme, dass konventioneller Landbau externe Umwelteffekte verursacht während umweltfreundliche alternative Produktionsmethoden nicht-handelbare Umwelt-nutzen generieren. Gleichzeitig erzielen alternativ produzierte Güter einen Preisaufschlag am Markt. Gezielte Politikeingriffe erfassen Interaktionseffekte zwischen externen Kosten und Nutzen: Umwelt-steuern auf Inputs reduzieren die Deckungsbeiträge, gleichzeitig aber auch die notwendigen Subventionen um umweltfreundlichere Produktionsweisen zu induzieren. Daher ist es nur dann optimal, umweltfreundliche Produktionsweisen zu subventionieren, wenn der zusätzliche Grenznutzen die Reduktion der externen Grenzkosten durch die Umweltsteuer übersteigt. Veränderungen in den Terms of Trade implizieren, dass große (relativ flächenreiche) Exporteure alternativ erzeugter Agrargüter strategische Anreize zur Überbewertung externer Kosteneffekte haben. Dagegen haben große (relativ flächenarme) Importeure strategische Anreize zur Überbewertung externer Nutzen. Das Modell kann daher auch dazu dienen, prinzipielle WTO-Verhandlungspositionen der Hauptakteure im Bereich Agrarumwelt zu erklären.

### Schlüsselwörter

Agrarumwelt, Internationaler Handel, Wohlfahrtsökonomie

## 1. Introduction

Beyond its primary function of producing food and fiber, agriculture contributes to achieve other important societal goals including the preservation of rural landscapes and a diverse natural environment. In theory, agricultural production should be complementary to these societal goals. However, modern agriculture is known to cause a number of negative environmental side effects. Examples include

nitrites which contaminate groundwater resources, pesticide residues that lead to public health concerns, irrigation practices that are responsible for saline soils and aquifers, as well as soil erosion, wetland degradation or biodiversity losses.

On the other hand, agricultural production is also associated with positive environmental effects (landscape, natural habitat and biodiversity preservation). People value a rural countryside as basic a element of a natural environment and their cultural heritage. Contingent valuation studies have verified substantial non-market values for the amenities associated with them (e.g. ROMMEL, 1998; AAKKULA, 1999). Over time, agriculture has given rise to rural landscapes that help to preserve natural habitats and biodiversity. Both the intensification of agriculture or the abandonment of agricultural land can harm these cultural and nature values of farmed landscapes.

The CAP reform of 1992 introduced agri-environmental programs to promote more environmentally benign production methods in the EU. In particular, Council Regulation 2078/92 encouraged farmers to carry out environmentally beneficial activities on their land. Regional or national authorities manage the programs with a decentralized management system, subject to commission approval. Considerable emphasis was placed on program evaluation and development. The complexity of interactions between agriculture and the environment and the need to improve program performance required a constant adjustment. Within five years, the Commission has approved 133 original programs and 218 amendments (EU, 1999c).

These programs reflect a growing interest in preserving a sustainable natural environment in rural areas (OECD, 2000; EU, 1999a). For example, about 1/3 of Germany's arable land was enrolled in agri-environmental programs in 1997 (BMELF, 1999). Within the EU, every seventh farm is enrolled in some agri-environmental program covering about 1/5 of total arable land. Their main goals are to reduce the environmental risks from agriculture especially with respect to water and soil quality and to promote production practices that preserve agricultural landscapes and a natural biodiversity (EU, 1999c). The costs are in part financed by the EU budget. Expenditures are about 4% of total EAGGF (European Agricultural Guarantee and Guidance Fund) guarantee expenditures. In Austria, Finland and Sweden, the farmland area covered by agri-environmental programs is over 50% (EU average = 20%). Luxembourg (76%), Germany (39%), Ireland (24%) and France (23%) are above the average while Belgium, Greece and Netherlands are clearly below the average with less than 2% of arable land

covered. The pattern of program acceptance by farmers also differs between the member states with Austria (78%), Finland (77%), and Sweden (64%) having the highest participation rates.

Many EU agri-environmental programs amount to voluntary land use restrictions including conditional input use and stocking densities, strict scheduling of farming and harvesting activities and/or the maintenance of buffer strips to reduce pesticide use and nutrient loss and/or to increase natural biodiversity. The land use restrictions are often combined with per-hectare subsidies or direct payments in order to compensate for the costs incurred or the resulting income loss. Stringent production constraints are imposed to minimize any production incentive effect from agri-environmental payments and the programs contribute to lower fertilizer application rates, the preservation of landscape elements and natural habitats as well as to the overall societal goal of environmental protection.

Current federal-level agri-environmental policy in the U.S. include a range of programs, but unlike the EU, these policies are targeted mainly at potential negative effects consequence of agriculture (BERNSTEIN et al., 2003). Instruments include conservation compliance mechanisms, voluntary land retirement programs, cost-share and incentive payments, tax incentives, insurance, and market-based trading schemes (USDA, 1999a). In recent years, the scope of targeted problems has gone beyond soil erosion to include water and air quality, wildlife habitats, and wetlands. USDA-administered programs to be used to counter possible adverse environmental impacts of production increases that may result from trade liberalization include:

*Environmental Quality Incentives Program (EQIP)*: Assists farmers through technical assistance, education, cost-sharing, and incentives payments in adopting management techniques that reduce non-point-source surface and groundwater pollution.

*Conservation Reserve Program (CRP)*: Provides rental payments to agricultural producers who retire environmentally sensitive cropland.

*Wetland Reserve Program (WRP)*: Assists landowners in returning farmed wetlands to their original condition through easement payments and restoration cost-sharing.

*Conservation Security Program (CSP)*: Provides payments to farmers in return for their use of a wide range of environmentally benign land management practices. The program will have three "tiers" for participation; higher tiers require greater conservation effort and offer larger payments. Existing practices can be enrolled.

*Grassland Reserve Program (GRP)*: Uses contracts or easements in conjunction with compensatory payments (up to 2 million acres to be protected from conversion to other uses).

Although the existence of joint positive and negative externalities is accepted in the literature, separate policy instrument aim at each problem and they are typically analyzed independently (POE, 1997). Payments for land use restrictions or land retirements are justified by non-market benefits (e.g. wildlife conservation) while input regulations are imposed because of negative environmental impacts (e.g. nitrate residues). An independent policy analysis ignores important interaction effects: polluting input taxes reduce

the returns and lower any subsidy needed to induce environmentally benign production. In general, an adjustment to one externality requires adjusting both policies (Reichel-derfer, 1990).

Trade and the environment issues related to agriculture continue to be on the international policy agenda (Ervin, 2001). Consumer groups, environmentalists and animal welfare activists see WTO rules as an obstacle to their interests. Farmers are concerned that high environmental, health, and animal welfare standards will affect their international competitiveness and argue for an equivalence of standards across countries. The 1999 WTO summit in Seattle made clear that these issues matter more to the general public in industrialized countries than tariff reductions or trade distorting price supports. Therefore, it is safe to say that the importance of agriculture in future WTO negotiations will be tied to the environmental functions it performs.

The Uruguay Round Agreement on Agriculture provides sufficient scope for governments to pursue 'non-trade' concerns including food security, the environment, structural adjustment, and rural development. Negotiations have to take non-trade concerns into account (Article 20). Within the WTO, a number of countries have produced studies to support the multifunctional role of agriculture. Others agreeing that everyone has non-trade concerns call for specific proposals so that the negotiations move on to discussing whether trade-distorting measures are justified. Most countries agree that agriculture is not only producing food and fiber, but also other "non-food" outputs which include non-trade objectives (WTO, 2001). The core question debated in the WTO is whether "trade-distorting" subsidies, or subsidies outside the "green box", are needed to help agriculture perform its many roles (LATACZ-LOHMAN, 2000).

Some countries will argue that all the objectives can be achieved more effectively via "green box" subsidies which are targeted directly at these objectives and minimally distort trade. Examples include environmental and regional assistance programs, food security stocks, direct payments to producers, structural adjustment assistance, and safety-net programs which do not stimulate agricultural production or affect prices. These countries say the burden is on the proponents of non-trade concerns to show that the existing provisions, which were the subject of lengthy negotiations in the Uruguay Round, are inadequate for dealing with these concerns in targeted, non-trade distorting ways. Other countries say the non-trade concerns are closely linked to production. They believe subsidies based on or related to production are needed for these purposes (e.g., rice fields must be promoted to prevent soil erosion).

Countries supporting the multifunctional role of agriculture typically share a number of common characteristics including high levels of income support and trade protection, high population densities and per capita incomes, and small scale farming systems. In contrast, the opponents are characterized by relatively low levels of income support and trade protection, lower population densities, and relatively large scale farming systems (BURRELL, 2001). The first group includes countries such as Japan, South Korea and Norway which place a lot of emphasis on the need to tackle agriculture's diversity as part of these non-trade concerns. The EU proposal says non-trade concerns should be target-

ted (e.g. environmental protection should be handled through environmental protection programs), transparent and cause minimal trade distortion. The opponent side includes many exporting developing countries which say proposals to deal with non-trade concerns outside the "green box" of non-distorting domestic supports amount to a form of special and differential treatment for rich countries. Several even argue that any economic activity has equal non-trade concerns, and therefore if the WTO is to address this issue, it has to do so in all areas of the negotiations, not only agriculture.

In this paper, agriculture generates joint positive and negative externalities. Trade impacts of policies addressing negative externalities has been analyzed in some detail (e.g. KRUTILLA, 1991; ANDERSON, 1992; COPELAND, 1994). However, few studies examine more relevant multiple externality cases (e.g. PETERSON, 1999; OLLIKAINEN, 1999). We analyze agri-environmental policy (direct payments or subsidies for environmental services in conjunction with polluting input regulations) to correct for joint externalities including their trade-distorting effects which are often ignored in the literature. The relevance for trade negotiations is highlighted by "green box" which ought to have no or minimal effect on trade or production (EU, 1999b).

The theoretical model presented here is based on an indirect utility approach (see also SCHAMEL, 1995; PETERSON, 1999 or MÆSTAD, 1998). However, we distinguish between *alternative* and *conventional* production systems that generate non-market benefits (landscape amenities) and external costs (pollution), respectively. We focus on the dichotomy between a "clean" production process, which generates non-market benefits, and a "polluting" production process, which does not. Unlike conventional production, alternative agriculture is characterized by less intensive but non-polluting input use at higher private costs. Similar to PAARLBERG et al. (2000), we argue that positive externalities occur because society values non-market attributes inhere generated by certain agricultural production methods, which should then be reflected in the social welfare function.

The paper is structured as follows: section 2 introduces a theoretical model for a closed economy and derives the social welfare-maximizing first-order conditions. Section 3 analyzes second-best agri-environmental policies to correct for the external effects. In section 4, we derive the terms of trade impacts of welfare maximizing factor allocations for large countries with free trade. Section 5 summarizes the main results and provides some additional policy implications.

## 2. Agricultural economy model

Consider an economy with many identical consumers that demand "alternative" and "conventional" food products, denoted by  $a$  and  $c$ , respectively. Agriculture can produce these goods according to the production functions  $a = F_a(L_a, X_a)$  and  $c = F_c(L_c, X_c)$  which are strictly increasing and concave and exhibit constant returns to scale.  $L_i$  and  $X_i$  are the amount of arable land and agricultural inputs allocated to the production of good  $i = a, c$ , respectively. The rural economy is endowed with  $L$  hectares of arable land and  $X$  units of agricultural inputs. Assuming homogeneity, we obtain  $F_i(L_i, X_i) = L_i F_i(1, X_i/L_i) = L_i f_i(x_i)$ , where  $x_i$  represents the per-hectare input ratio  $X_i/L_i$  and  $f_i(\cdot)$  is per-hectare production. Alternative agricultural production is less productive such that  $f_a(x_a) < f_c(x_c)$  and  $f'_a(x_a) < f'_c(x_c)$ .

Agriculture creates two externalities. First, consumers obtain amenity benefits from land in alternative agriculture  $L_a$ . Second, conventional production generates environmental damage according to  $E = L_c e(x_c)$ , where  $e(\cdot)$  are emissions per hectare. Emissions are homogeneous of degree one and will double if  $L_c$  and  $X_c$  double such that  $x_c$  remains constant. Assume that  $e(\cdot)$  is strictly increasing, strictly convex, and that  $e(0) = 0$ . Moreover, assume that impact of emissions cannot be measured directly at the source (e.g. nitrate pollution of groundwater).

Consumer preferences are given by an aggregate utility function  $U(a, c, L_a, E)$ , which is strictly quasi-concave, strictly increasing in  $(a, c, L_a)$ , and strictly decreasing in  $E$ . Consumers use their income  $I$  to purchase  $a$  and  $c$ , but cannot influence  $L_a$  and  $E$ . Let  $c$  be the numeraire good and  $p$  the price of  $a$ . Then, indirect utility function  $V$  is defined by:

$$V(p, I, L_a, E) = \max U(a, c, L_a, E) \\ \text{s.t. } pa + c \leq I, \quad (a, c) \in \mathbb{R}_+^2$$

$V(\cdot)$  is the social welfare with an optimal combination of price, income, arable land allocation, and emissions.  $a(p, I, \cdot)$  and  $c(p, I, \cdot)$  are the demands for alternative and conventional commodities, respectively and solve the utility maximization problem stated above. If the utility function is properly restricted and the demand functions are monotonic in  $p$ , there is a unique price that will clear both markets. With constant returns to scale, income  $I$  is equal to total factor payments in agricultural production which are equal to revenues. Thus,  $p$  and  $I$  are functions of  $L_a$  and  $x_a$ , and these relationships are implicitly defined by the equations:

$$[1] \quad a(p(L_a, x_a), I(L_a, x_a), \cdot) = L_a f_a(x_a)$$

$$[2] \quad I(L_a, x_a) = p(L_a, x_a) L_a f_a(x_a) + (L - L_a) f_c(x_c(L_a, x_a))$$

where  $x_c(L_a, x_a) = (xL - x_a L_a)/(L - L_a)$ , and  $x = X/L$ . Therefore, the problem of maximizing social welfare in a closed economy is:

$$\max V[p(L_a, x_a), I(L_a, x_a), L_a, (L - L_a)e(x_c(L_a, x_a))]$$

$$\text{s.t. } L_a \in [0, L], x_a \in [0, xL/L_a]$$

When  $p(\cdot)$ ,  $I(\cdot)$ , and  $e(\cdot)$  are continuous and the constraint set is compact, an optimal solution exists. Appropriate assumptions on  $U(\cdot)$  and  $F_i(\cdot)$  exclude corner solutions such that consumer preferences for  $a$  guarantee that a positive level of non-market amenity benefits is provided by farmers that engage in alternative production methods.<sup>1</sup> An interior solution satisfies the first-order conditions:

<sup>1</sup> If marginal utilities and marginal products approach infinity as their arguments approach zero, both factors are allocated to both commodities. With an interior solution,  $p > 1$  because alternative agriculture is characterized by less intensive input use at a higher per unit cost of production.

$$[3] \quad \frac{\partial V}{\partial L_a} = V_p p_L + V_L I_L + V_L + V_E [-e(\cdot) + L_c e'(\partial x_c / \partial L_a)] = 0$$

$$[4] \quad \frac{\partial V}{\partial x_a} = V_p p_x + V_L I_x + V_E L_c e'(\partial x_c / \partial x_a) = 0$$

where subscripts denote partial derivatives with respect to  $L_a$  and  $x_a$  unless noted otherwise. Roy's Identity yields  $V_p = -a(p, I, \cdot)V_I$ . Utility maximization requires that  $p(\cdot) = U_a/U_c$  and from the envelope theorem we know that  $V_I = U_c$ ,  $V_L = U_L$ , and  $V_E = U_E$ . After substituting these conditions, the partial derivatives of  $I(L_a, x_a)$  from [2], and the market clearing condition [1] into [3] and [4], we obtain two expressions in terms of the utility and production functions:

$$[5] \quad \frac{U_a}{U_c} f_a(\cdot) + \frac{U_L}{U_c} = \frac{U_E}{U_c} [e(\cdot) - e'(\cdot)(x_c - x_a)] + [f_c(\cdot) - f'_c(\cdot)(x_c - x_a)]$$

$$[6] \quad \frac{U_a}{U_c} f'_a(\cdot) = f'_c(\cdot) + \frac{U_E}{U_c} e'(\cdot)$$

Equation [5] defines the optimal allocation of  $L_a$ . The LHS is the marginal benefit of using arable land for alternative production plus the marginal amenity value of alternative land use; the RHS is the marginal opportunity value of using arable land to produce  $c$  minus the marginal opportunity cost of resulting emissions ( $U_E < 0$ ). Equation [6] determines the optimal input choice  $x_a$  by equating marginal per hectare benefits of producing  $a$  and the marginal opportunity value net of external cost in terms of conventional production  $c$  foregone. Equations [5] and [6] are a simultaneous system and define the optimal choice of  $L_a$  and  $x_a$ . Note that the partial derivatives of  $U(\cdot)$  must be evaluated at the socially optimal factor allocation for equations [5] and [6] to define a social welfare optimum.

### 3. Optimal agri-environmental policy

Without policy intervention, the market will not provide for optimal levels of emissions and amenity benefits. The factor allocation will not reflect social preferences and farmers will under-supply alternative and over-supply conventional commodities. A policy combination that could directly target emissions  $E(L_c, X_c)$  and alternative land use  $L_a$  would internalize both external effects and yield a social optimum. However, a direct emissions tax is not feasible when the impact of the negative externality cannot be measured. Thus, a second-best emissions policy will target polluting inputs. Consider three policy instruments: a polluting input tax ( $t_X$ ), and subsidies for alternative land use ( $s$ ) as well as alternative production ( $\sigma$ ). Two instruments are imposed jointly, because of the two external effects in the model. Imposing only one instrument could not provide for both externalities. Imposing a joint third instrument would allow for one degree of freedom in choosing optimal policy levels. We analyze two cases:

(1) alternative land use subsidy ( $s$ ) plus polluting input tax ( $t_X$ ) with  $\sigma = 0$ .

(2) alternative production subsidy ( $\sigma$ ) plus polluting input tax ( $t_X$ ) with  $s = 0$ .

From duality theory, we know that the factor allocation, the policy variables ( $\sigma, s, t_X$ ) and the price  $p$  describe producer behavior via a revenue function  $R(L_a, x_a, \sigma, s, t_X, p)$ :

$$R(\cdot) = \max[(p + \sigma)L_a f_a(\cdot) + sL_a - t_X(L - L_a)x_c + (L - L_a)f_c(\cdot)]$$

$$s.t. \quad L_a \in [0, L], \quad x_a \in [0, XL/L_a]$$

Strict concavity assumptions imply that a unique interior solution must satisfy the following first-order conditions:

$$[7] \quad (p + \sigma)f_a(\cdot) + s + t_X x_a = [f_c(\cdot) - f'_c(\cdot)(x_c - x_a)]$$

$$[8] \quad (p + \sigma)f'_a(\cdot) + t_X = f'_c(\cdot)$$

Since  $U_a/U_c = p(\cdot)$  we may compare [6] to [8] and [5] to [7], to conclude that the welfare-maximizing policy variables ( $\sigma, s, t_X$ ) must satisfy:

$$[9] \quad \sigma f'_a(\cdot) + t_X = -\frac{U_E}{U_c} e'(\cdot)$$

$$[10] \quad \sigma f_a(\cdot) + s + t_X x_a = \frac{U_L}{U_c} - \frac{U_E}{U_c} [e(\cdot) - e'(\cdot)(x_c - x_a)]$$

#### Case (1): Alternative land use subsidy ( $s$ ) and polluting input tax ( $t_X$ ).

In this case, a direct land subsidy targets the positive externality. Farmers enrolling their land in an agri-environmental program would receive a per-hectare subsidy for the non-market benefits generated. Farmers not enrolled would face a polluting input tax. An example for such a policy scenario could be a countryside stewardship program paying a (de-coupled) per hectare subsidy upon enrollment in conjunction with a nitrogen tax charged to non-participants. When  $\sigma = 0$ , equations [9] and [10] yield

$$s = U_L/U_c - U_E/U_c [e(\cdot) - e'(\cdot)x_c] \text{ and } t_X = -[U_E/U_c] e'(\cdot).$$

If polluting inputs are taxed at the Pigouvian rate  $t_X$ , it is optimal to subsidize alternative land use at a rate less than the marginal amenity benefit  $U_L/U_c$  because the polluting input tax  $t_X$  already provides an incentive for alternative land use. It can be shown that the subsidy correction term  $-U_E/U_c [e(\cdot) - e'(\cdot)x_c]$  in equation [10] is negative.<sup>2</sup> Therefore, the optimal alternative land use subsidy  $s$  is positive only if the marginal amenity benefit from alternative land use exceeds the marginal pollution cost savings  $U_E/U_c [e(\cdot) - e'(\cdot)x_c]$  from the land shifting out of conventional use. In other words, it only makes sense to subsidize alternative land use when the amenity benefit gained is larger than the reduced social costs of pollution from conventional production facing a polluting input tax. While this result is a very intuitive, it differs sharply from PETERSON

<sup>2</sup> Because  $e(\cdot)$  is convex and  $e(0) = 0$ , the expression  $[e(\cdot) - e'(\cdot)x_c]$  is negative which combined with the fact that  $U_E < 0$ , implies that  $s < U_L/U_c$ .

(1999) where agricultural land should always be subsidized. In the absence of a polluting input tax ( $t_X = 0$ ), the optimal alternative land subsidy implied by conditions [9] and [10] would be positive and equal to  $U_L/U_c - U_E/U_c e'(\cdot)$ .

Two more general conclusions follow from [9] and [10]. First, when alternative land use provides no amenity benefits ( $U_L = 0$ ), a Pigouvian input tax  $t_X = -(U_E/U_c)e'(\cdot)$  would shift too much land into alternative use requiring an alternative land tax  $s < 0$ . This conclusion would also hold when only conventional production pollutes, but both systems provide amenity benefits. This result is also differs from PETERSON (1999) in the sense that it is not always required to subsidize agricultural land for the non-market amenity benefits: a polluting input tax may already provide for enough amenities. Second, when conventional production is non-polluting ( $U_E = 0$ ) while alternative land use creates amenity benefits ( $U_L > 0$ ), it would be optimal to subsidize alternative (or tax conventional) land use at  $U_L/U_c$ .

#### Case (2): Alternative production subsidy ( $\sigma$ ) and polluting input tax ( $t_X$ ).

In this case, an indirect production subsidy targets the positive externality while the land market is not regulated. Upon enrollment in an agri-environmental program, farmers would receive an output subsidy. An example for such a policy setting would be to link price support policies to environmentally benign production methods. For program non-participants, polluting inputs would be taxed. When  $s = 0$ , equations [9] and [10] yield

$$\sigma = \frac{U_L - U_E [e'(\cdot) - e'(\cdot)x_c]}{U_c [f_a(\cdot) - f_a'(\cdot)x_a]}$$

and

$$t_X = -[U_E/U_c]e'(\cdot) - \sigma f_a'(\cdot).$$

$\sigma$  is less than the marginal amenity benefit  $[U_L/U_c]/[f_a - f_a'x_a]$  from additional alternative output.  $\sigma$  is positive when marginal amenity benefits from alternative production exceed the pollution cost savings from less conventional production. In other words, it is only beneficial to subsidize alternative production when amenity benefits gained are larger than the cost of pollution saved from conventional production. Now, the optimal input tax  $t_X$  is less than in case (1) because the production subsidy also provides an incentive to move polluting inputs into clean production (i.e. the marginal per-hectare impact of an alternative output subsidy  $-\sigma f_a'$  is negative). When this impact exceeds the marginal per-hectare welfare effect of emissions (i.e.  $\sigma f_a' \geq -U_E/U_c e'$ ), the optimal polluting input tax  $t_X$  would become negative and turn into a subsidy. This would imply that the commodity policy would shift too much land into alternative production. However, only one of the two instruments ( $\sigma$  or  $t_X$ ) can be negative.

Two more general conclusions also follow. First, when alternative land use provides no amenities ( $U_L = 0$ ),  $\sigma < 0$  and a polluting input tax  $t_X = -(U_E/U_c)e' - \sigma f_a'$  would imply excessive alternative production. Again, the polluting input tax may already provide for enough amenity benefits. This conclusion would also hold when only conventional production pollutes and both systems provide for amenities.

Second, when conventional production is non-polluting ( $U_E = 0$ ) and alternative land use creates amenity benefits ( $U_L > 0$ ), an alternative output subsidy  $U_L/U_c[f_a - f_a'x_a]$  would also lead to excess alternative production such that  $t_X < 0$ .

## 4. Open economy model

Suppose that agricultural commerce is now open to international trade. Domestic agriculture generates positive and negative externalities as described above without cross-border effects. If the domestic country is large relative to the world market, prices  $p(\cdot)$  are endogenous and the policy problem to maximize social welfare becomes:

$$\max V[p(L_a, x_a), I(L_a, x_a), L_a, (L-L_a)e(x_c(L_a, x_a))]$$

$$L_a \in [0, L], x_a \in [0, xL/L_a]$$

The price and income relations  $p(\cdot)$  and  $I(\cdot)$  satisfy:

$$[11] \quad a(p(L_a, x_a), I(L_a, x_a), \cdot) = L_a f_a(x_a) + a^*(p(L_a, x_a))$$

$$[12] \quad I(L_a, x_a) = p(L_a, x_a)L_a f_a(x_a) + (L-L_a)f_c(x_c(L_a, x_a))$$

where  $a^*(\cdot)$  is foreign excess supply. The first-order conditions for a large country are:

$$\begin{aligned} \partial V / \partial L_a &= V_p p_L + V_L I_L + V_L + \\ V_E [-e'(\cdot) + L_c e'(\partial x_c / \partial L_a)] &= 0 \end{aligned}$$

and

$$\partial V / \partial x_a = V_p p_x + V_L I_x + V_E L_c e'(\partial x_c / \partial x_a) = 0.$$

After substituting Roy's Identity  $V_p = -aV_L$  and  $V_L = U_c$ ,  $V_L = U_L$ ,  $V_E = U_E$ , the derivatives  $I_L$  and  $I_x$ , the condition  $p = U_a/U_c$ , and the market clearing condition [11], it follows:

$$[13] \quad pf_a(\cdot) - a^*(p)p_L + \frac{U_L}{U_c} = \frac{U_E}{U_c} [e'(\cdot) - e'(\cdot)(x_c - x_a)] + [f_c(\cdot) - f_c'(\cdot)(x_c - x_a)]$$

$$[14] \quad pf_a'(\cdot) - a^*(p)p_x = f_c'(\cdot) + \frac{U_E}{U_c} e'(\cdot)$$

Conditions [13] and [14] contain an extra term  $-a^*(\cdot)p_j$  ( $j = L_a, x_a$ ) when compared to [5] and [6]. Since  $a_p < 0$  and  $a_p^* > 0$ , the partial derivatives of condition [11] with respect to  $L_a$  and  $x_a$  imply that  $p_L < 0$  and  $p_x < 0$ . Therefore, world market prices decline when the allocation of factors to alternative agriculture increases. For an economy importing alternative commodities,  $a^*(\cdot) > 0$  and  $-a^*(\cdot)p_j$  is positive. Then, the marginal benefits from alternative production are higher for a importer that raises the alternative factor share. If a country exports alternative commodities,  $a^*(\cdot) < 0$  and  $-a^*(\cdot)p_j$  is negative. Then, the marginal benefits from alternative production are higher if the exporter decreases the alternative factor share. This is intuitive because large importers incur strategic gains from lower while large exporters incur strategic gains from higher world market prices.

If agricultural land is relatively abundant (scarce) in the domestic economy, standard trade theory predicts a compa-

rative advantage in producing alternative (conventional) commodities. Thus, we could deduce that land abundant countries in theory have a comparative advantage to produce alternative commodities relative to land scarce countries. However, the external benefits (costs) associated with alternative (conventional) production are usually non-tradable. The associated strategic positions create incentives to increase alternative production for importers because it will (a) improve the terms of trade and (b) increase the availability of the non-tradable amenity good while decreasing external costs. For an exporter, the strategic position (incentives to increase conventional production) is less favorable as it will only improve the terms of trade.

For agri-environmental policies justified on externality grounds, the open economy model presented here predicts that a potentially large exporter of alternative commodities (e.g. US) has a strategic incentive to overrate the external costs and to restrict the use of polluting inputs. In contrast, the model would predict that a potentially large importer of alternative commodities (e.g. EU) has an incentive to overrate the non-market benefits of alternative land use and therefore to promote environmentally friendly production methods. These predictions are in line with the current negotiating positions of two major agricultural players within the WTO. The EU as a relatively land scarce importer of agricultural goods is stressing the importance of positive externalities related to agriculture (EU, 1999b). This position is consistent with incentives to overvalue non-market benefits due to alternative agricultural production methods. In contrast, the US as a land abundant exporter of agricultural goods is stressing the importance of negative externalities that are related to modern agricultural production techniques (USDA, 1999b). This position is consistent with incentives to overvalue the external costs due to conventional agricultural production.

## 5. Summary and policy implications

In this paper, we derive conditions for optimal policies when agriculture creates two interdependent externalities: emissions from conventional production activity and amenity benefits from an environmentally friendly agriculture. Without policy intervention, the market will not provide for optimal levels of emissions and amenity benefits and farmers will under-supply alternative and over-supply conventional commodities. Direct emission taxes are not feasible because the negative externality cannot be measured. Therefore, a second-best policy must target polluting inputs.

Two cases are analyzed where two policy instruments are imposed jointly. In case (1), farmers who enroll their land in an agri-environmental program would receive a per-hectare subsidy for the non-market benefits generated while production on land that is not enrolled would face a polluting input tax. In case (2), farmers enrolled in an agri-environmental program would receive a production subsidy for the non-market benefits generated by their alternative land use while conventional production methods would face polluting input taxes. It would be optimal to subsidize land in case (1) [or production in case (2)] at a rate less than the additional marginal amenity benefits provided because the concurrent polluting input tax already provides an incentive to move away from conventional production. Consequently,

per-hectare amenity benefits derived from contingent valuation studies may not be an appropriate estimate for an alternative land use subsidy.

However, the optimal land (or production) subsidy is positive only if the additional marginal amenity benefit exceeds the pollution cost savings from input tax induced reductions in conventional production. In other words, it only makes sense to subsidize alternative land use (or production) when the amenity benefit gained is larger than the external cost reductions due to the polluting input tax. Thus, the higher society values amenities ( $U_L$ ) relative to pollution ( $U_E$ ) the more it will justify policies that foster environmentally benign production and restrict polluting inputs. The optimal polluting input tax is lower in case (2) because the production subsidy provides additional incentives towards cleaner production methods.

Two more general conclusions were derived. First, when alternative land use provides no amenity benefits ( $U_L=0$ ), a Pigouvian input tax would shift too much land into alternative use and would require an alternative land (or production) tax. Second, when conventional production is non-polluting ( $U_E=0$ ) while alternative land use creates amenity benefits, a Pigouvian land subsidy would be optimal in case (1), while in case (2) a second-best alternative output subsidy would lead to excessive alternative production.

With trade, large importers gain from policies that decrease world prices while exporters gain from policies that increase world prices. Thus, large importers have an incentive to overrate the benefits of alternative production while large exporters have an incentive to overrate the social costs of conventional production. Standard trade theory would predict a comparative advantage in producing alternative (conventional) commodities when agricultural land is relatively abundant (scarce) in the domestic economy. For agri-environmental policies justified on externality grounds, the model would predict that a potentially large exporter of alternative commodities like the US has an incentive to overrate the external costs and to restrict the use of polluting inputs. In contrast, a potentially large importer of alternative commodities like the EU has an incentive to overrate the non-market benefits of alternative land use and therefore to promote environmentally friendly production methods.

These predictions could also explain some of the current positions of major agricultural players within the WTO negotiations. Large importer of agricultural goods like the EU are stressing the importance of positive externalities related to a multifunctional agricultural sector (EU, 1999b). In contrast, large exporter of agricultural goods like the US are stressing the need to address negative externalities that are related to modern agricultural production techniques (BERNSTEIN et al., 2003; ANDERSON, 1998). However, both positions may actually imply terms of trade effects and distort international trade.

Positive and negative agricultural externalities often vary between regions requiring location-specific policy implementation. For example, amenity benefits and pollution damages are large around metropolitan areas or in densely populated countries, where targeted policies would discourage conventional and encourage alternative agriculture (e.g. restricted land use in nature reserves, organic farming). The model shows that local land use regulations will not guarantee an optimal land allocation without suitable

polluting input regulations in place. Moreover, the environment and farm income support may be complementary policy goals. However, using a "carrot" to support (environmentally benign) production and thus also farm income without concurrently restricting polluting input use may be socially inefficient if the "stick" is less costly in curtailing conventional production activities. Although the analysis in this paper has focused on agri-environmental policies and their effect on the socially optimal factor allocation, the model can be extended to analyze their effects on agricultural markets, incomes, and pollution.

The model supports three broad policy implications to achieve agri-environmental policy goals. First, further reform of agricultural policy to allow for more trade liberalization and growing environmental concerns (e.g. remove incentives to over-apply chemicals, to over-plant chemical-intensive crops, and to farm environmentally sensitive land). This requires a clear set policy criteria to avoid potential conflict (BLANDFORD, 2001). Second, devise programs that promote the (voluntary) adoption of cost effective technologies and management practices to improve agri-environmental conditions. Third, promote research, development, and the transfer of new technologies to meet current and anticipate future demands on environmental quality.

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