Killing two birds with one stone: the U.S. and the E.U. biofuel programs

Jean-Marc Bourgeon* David Treguer†

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Abstract

Several countries have recently impulsed biofuel policies to mitigate Greenhouse Gas (GHG) emissions of fossil fuels and also to secure their energy supply. The price increase due to this new demand for feedstock reduces the need for farm support programs. Subsidy policies aiming at reaching relatively low production levels of biofuel may actually lead to a decrease in the total public outlay. For larger biofuel production objectives, the total public spending is more likely to be larger, but the social cost of the biofuel programs is lower than the corresponding public spending. Diminishing the cost of farm support programs induces relatively low levels of imports of agricultural feedstocks and larger subsidies for biofuel produced from domestic feedstock than from imports.

Keywords: Biofuels, Income support, Environmental enforcement.

1 Introduction

In the European Union (EU) as in the United States (USA), new programs aim at developing biofuels significantly. As pointed out by several studies (see, e.g. Togkoz et al., 2006 and Dronne and Gohin, 2006), subsidizing the

*INRA and Ecole Polytechnique, Paris.
†INRA and AgroParisTech, Paris.

biofuel industry raises the price of the agricultural feedstock.[1] In the EU, the development of biofuel production will allow the agricultural sector to benefit from a dual support (taken in a broad sense): on the one hand, states hand out decoupled payments to farmers (Single Farm Payments), and on the other, states give a large support to the biofuel industries, whose production costs exceed the price at which they can sell their output. The price increase in the agricultural commodities raises the farmers' revenues, and reduces the need for direct income support. Hence, for a given objective of agricultural income, the regulator is able to operate a partial substitution between direct agricultural income support and subsidies to the biofuel industry. Owing to the importance of the Common Agricultural Policy (CAP) in the EU budget (50 billion euros per year, i.e. 46% of the EU budget), the question of a partial substitution of biofuel subsidies for CAP payments could be on the EU political agenda very soon. In the USA, the ethanol program might lead to a long-lasting price increase for corn, wheat and soybeans, which could temporarily stop the counter-cyclical and loan deficiency payments (Babcock, 2006). Of course, this competition with biofuel firms for the same input is harmful for the European agro-food industry, which stands up against the policy in favor of the first generation of biofuels (see Unilever, 2006, Forbes, 2006 and Confederation of the food and drink industries of the EU, 2006). Goldman Sachs (Financial Times, 2006) also points to a possible decrease in agro-food firms' profits owing to biofuel production. With rising revenues for farmers, decreasing profits for the agro-food industry and a reduced consumer surplus, the net effect on the European welfare is unclear.

We develop a model that examines the possible decrease in the decoupled payments that the biofuel subsidy may trigger. We show that without constraint on biofuel production (coming, e.g., from security of energy supply concerns), the total public expenditure (i.e. biofuel subsidies and decoupled payments) may be lower than the public spending corresponding to the initial farm support program. From this policy shift, the taxpayer gains, the farmer is indifferent while the agro-food firms and the consumer lose. However, it may be socially beneficial to implement such policies if public funds are costly. This result may explain why biofuel programs have been in place in the EU and the US for more than a decade. For constraining biofuel production objectives, the total public spending is more likely to be increased, but because

[1] The so-called first generation of biofuels is produced using crops identical to those used by the food processing industry. Hence, a competition is likely to take place between food and energy crops for the agricultural feedstock. In the EU, this competition mainly involves rapeseed, which is valuable both for the agro-food and the biodiesel industries. In the USA, the main biofuel being corn ethanol, the competition concerns the ethanol processing industries and cattle breeders.

of the substitution effect between the two subsidy policies, the cost of the biofuel programs is lower than the corresponding public spending. Considering the possibility of importing the agricultural feedstock, the government may still take advantage of the substitution between the farm support program and the biofuel subsidy policy. This effect leads to a domestic price of the agricultural commodity higher than the world price, relatively low import levels, and biofuel produced from imported agricultural feedstock benefiting from a lower subsidy than biofuel produced from the domestic input. When the biofuel production constraint is binding, we also obtain that the optimal domestic production of feedstock exceeds the optimal (unconstrained) level of supply of agricultural raw product that prevails in autarky.

The effects of biofuels on environmental policies are double-edged. On the one hand, biofuels are one of the main features of the GHG mitigation policies in the transportation sector. On the other hand, the sizeable production of energy crops will have major implications on environmental policies for the agricultural sector. Hence, the environmental externalities are positive for the GHG emissions, but negative for the agricultural production. There is thus an essential contradiction between setting a prominent objective for biofuel production that will lead (through higher prices) to higher yields and thus to an intensification of the agricultural production, and the adoption of sound agricultural practices.[2] The positive environmental externalities of biofuels regarding GHG emissions ought to be weighed against the negative externalities generated by the production process of the agricultural raw material. We analyze the optimal trade-off between GHG mitigation and a sound agricultural production. We show that because of the social cost of public funds, the optimal standard is stricter than the Pigovian level. Indeed, by setting a stringent environmental standard, the regulator increases the marginal cost of production, hence the price of the agricultural feedstock, which reinforces the substitution effect between the biofuel subsidy policy and the farm support program. However, this standard is less stringent taking account of the cost of enforcing the environmental policy. We analyze the effects of monitoring cost on the biofuel production (assuming that production levels are not constrained) and on the agricultural environmental standard. We also characterize the distortions induced by the cross compliance provisions of agricultural support programs.

The paper is organized as follows. First, our model is presented and the optimal production of energy crop is derived. The following section deals with the import scenario. Last, the environmental consequences of the

[2]The increased production of corn might well lead to local pollution problems, as well as soil erosion concerns (Marshall and Greenhalgh, 2006).

increased agricultural production is addressed, notably in what pertains to the enforcement of the environmental policies directed to agriculture.

2 The model

Consider two sectors of an economy, a food sector and an energy sector (referred to as "F" and "E" respectively) that use the same homogeneous agricultural feedstock in order to produce their own outputs (food products and biofuels, respectively). Hence, the total quantity of the agricultural product, X , is split between the food (x_F) and the energy (x_E) sectors: $X = x_F + x_E$. The representative firm in the food industry has a production function given by: $y_F = f(x_F) = K^{1-a}x_F^a$, where K is the capital level and a a positive parameter, $0 < a < 1$. The production function of the energy sector is $f_E(x_E) = \gamma_E x_E$, where $\gamma_E < 1$ is a positive parameter. All agents in this economy are price-takers, with an agricultural inverse supply function $w(X)$, with $w'(X) > 0$, and prices $p_F(y_F)$ and p_E for the food and the energy sectors. p_E is supposed unaffected by the production of biofuel. We assume that energy firms cannot operate without subsidy, i.e. that we have $p_E\gamma_E < w(X_0)$, where X_0 is the total quantity of crops produced and bought by the food industry when no biofuel is produced. If the regulator desires to reach a given minimum biofuel production level Q (for GHG mitigation objectives or security of supply concerns), which corresponds to an input demand $x_E = Q/\gamma$, it has decided to grant energy firms a per unit subsidy[3] given by

$$\sigma_E = w(X)/\gamma_E - p_E$$

which allows biofuel firms to break even.[4] As $w'(X) > 0$, the subsidy should rise with the desired quantity of energy crops, as the price of the domestic crop becomes higher. However, an higher price should lead to a decrease in the demand coming from the food industry. It is easily seen that the net effect of an increase in the biofuel production level is that the aggregate quantity of agricultural production X increases while x_F decreases. Indeed, solving the program of the representative firm of the food industry given by

$$\Pi_F \equiv \max_x p_F(y_F)f_F(x) - w(X)x, \tag{1}$$

[3] Of course, other policies are possible, like mandatory blending or, first of all, a Pigovian tax on fossil fuels. Focusing on the currently favored subsidy policies, we shall not discuss these alternative policies in the following.

[4] We assume that the energy firm has no private information: its technology and cost structures are perfectly known to the regulator.

where $p_F(y_F)$ and $w(X)$ are considered as constant, the equilibrium condition on the input market leads to an optimal input demand x_F satisfying

$$ap_F(y_F)y_F/x_F - w(x_F + x_E) = 0, \tag{2}$$

for all $x_E \geq 0$, which implicitly defines x_F as a function of x_E. Applying the implicit function theorem to (2), we get:

$$\begin{aligned}\frac{dx_F}{dx_E} &= \frac{-w'(X)}{w'(X) + w(X)/x_F - a^2 y_F/x_F^2[p_F(y_F) + p'_F(y_F)y_F]} \\ &= -\left[1 + (1 - a + a/\epsilon_F^d)\epsilon_A^s X/x_F\right]^{-1}\end{aligned}$$

where $\epsilon_A^s = w(X)/[w'(X)X]$ is the elasticity of the agricultural supply and $\epsilon_F^d = -p_F(y_F)/[p'_F(y_F)y_F]$ the elasticity of the demand for agro-food products. We thus have $0 > dx_F/dx_E > -1$ and consequently

$$\frac{dX}{dx_E} = 1 + \frac{dx_F}{dx_E} > 0.$$

Hence, an increase in the biofuel demand increases the total demand for the agricultural raw product while the demand coming from the food sector decreases. The effects on the agricultural surplus, the profit of the food sector and on the consumers are derived straightforwardly. The agricultural surplus is given by:

$$\Pi_A = \int_0^X [w(X) - w(x)]dx$$

and we have

$$\frac{d\Pi_A}{dx_E} = X\left[1 + \frac{dx_F}{dx_E}\right] w'(X) > 0$$

For the food sector, applying the envelop theorem on (1), we arrive at:

$$\begin{aligned}\frac{d\Pi_F}{dx_E} &= p'_F(y_F)a\frac{y_F^2}{x_F}\frac{dx_F}{dx_E} - x_F w'(X)\left[1 + \frac{dx_F}{dx_E}\right] \\ &= \frac{-(1-a)w'(X)w(X)[p'_F(y_F)y_F/p_F(x) + 1]}{w'(X) + w(X)/x_F - a^2 y_F/x_F^2[p_F(y_F) + p'_F(y_F)y_F]}\end{aligned}$$

which is positive when $\epsilon_F \leq 1$ and negative otherwise. Finally, for the consumer' surplus, given by $CS = \int_0^{y_F}[p_F(y) - p_F(y_F)]dy$, we have:

$$\frac{dCS}{dx_E} = -p'_F(y_F)a\frac{y_F}{x_F}\frac{dx_F}{dx_E} < 0$$

The following lemma summarizes these results:

Lemma 1 *As the quantity of energy crops subsidized by the regulator increases, the agricultural surplus becomes higher while the consumer's surplus decreases. The agro-food industry may gain* ($\epsilon_F < 1$) *or lose* ($\epsilon_F > 1$) *depending on the elasticity of the demand. The energy sector makes no profit:* $\Pi_E = 0$ *(as the subsidy is perfectly adjusted).*

2.1 The Social Welfare Function

The objective of the regulator in to maximize the sum of the surpluses of the different agents in the economy: the farmers, the food and the energy industries, the consumer, and the taxpayers. It also accounts for a guaranteed income $\overline{\Pi}_A$ for the farmers. Hence, the taxpayers must finance the biofuel program on the one hand and the direct payments to the farmers. The total cost for subsidizing the energy crops is given by $\gamma_E x_E \sigma_E$, while the parity income constraint lead to a spending equal to $\overline{\Pi}_A - \Pi_A$. The total public spending is affected by $1 + \lambda$ in the Social Welfare Function (SWF), where λ is a positive parameter representing the opportunity cost of public funds. Last, an environmental benefit stemming from the GHG mitigation effects of biofuels is also accounted for in the SWF: let $B(x_E)$ be this environmental benefit and assume that $B'(x_E) = q$, where q is a positive parameter. As explain above, the profit of the biofuel industry is equals to zero. The program of the regulator takes the following form:[5]

$$\max_{x_E}\{W = \overline{\Pi}_A + CS + \Pi_F - (1+\lambda)[\gamma_E x_E \sigma_E + \overline{\Pi}_A - \Pi_A] + B(x_E) : x_E \geq Q/\gamma_E\}$$

Neglecting the constraint on the biofuel level, the optimal input demand of the energy sector, x_E^*, satisfies the following first-order condition:

$$\lambda x_F w'(X) dX/dx_E + q - (1+\lambda)[w(X) - p_E\gamma_E] \leq 0 \qquad (x_E^* \geq 0). \tag{3}$$

To interpret (3), consider the case $\lambda = 0$. We would have

$$q - [w(X) - p_E\gamma_E]$$

i.e., the Pigovian rule that the optimal subsidy should equalize the marginal benefit of GHG mitigation. With $\lambda > 0$, (3) states that the optimal subsidy for biofuel (which entail the shadow cost of public funds) must exceeds the marginal benefit of GHG mitigation. Indeed, absent any constraint on the biofuel production (i.e. $Q = 0$), the regulator must choose a quantity of

[5] We assume that this problem is unambiguously concave.

energy crops up to the point where the marginal social loss of subsidizing the biofuel sector equals the sum of the GHG positive externality and the marginal social gain of the transfer of revenue from the food sector to farmers. Indeed, the increase in the price of the agricultural raw product allows to diminish the direct payment to farmers: a marginal increase dx_E in the biofuel demand transfer a revenue equal to $x_F w'(X)dX/dx_E$ from the food industry to the farmers. This transfer allows to reduce the extend of the farm support program, hence the corresponding tax distortions caused in the rest of the economy. The reader can readily verify that for large level of x_F, the total subsidy outlay may effectively diminish. We have

$$\begin{aligned}\frac{d}{dx_E}\left[\gamma_E x_E \sigma_E + \overline{\Pi}_A - \Pi_A\right] &= \frac{d}{dx_E}\left[x_E(w(X) - p_E\gamma_E) - \int_0^X [w(X) - w(x)]dx\right] \\ &= w(X) - p_E\gamma_E - x_F w'(X)\frac{dX}{dx_E} \\ &= w(X)\left[\frac{w(X) - p_E\gamma_E}{w(X)} - \frac{dX}{dx_E}\frac{x_F}{X}\frac{1}{\epsilon(X)}\right]\end{aligned}$$

where $\epsilon(X)$ is the price elasticity of the agricultural crop supply, given by $\epsilon(X) = w(X)/[Xw'(X)]$. Hence, the variation of the total tax may be negative provided that the elasticity of the agricultural supply is low and x_F/X, the share of the food demand in the total demand of crops, is large. Hence, a sufficient condition to have a strictly positive level of biofuel at the optimum of the government's program is that (3) being strictly positive when no biofuel program is in place and all the agricultural crops serves as an input for the food industry (i.e., $x_E = 0$ which implies $x_F = X_0$):

$$q + \lambda X_0 w'(X_0)(dX/dx_E)|_{x_E=0} - (1+\lambda)[w(X_0) - p_E\gamma_E] > 0$$

Leaving apart GHG mitigation concerns (i.e. even with $q = 0$), we have $x_E^* > 0$ if $\lambda \geq \lambda_s$ defined by:

$$\lambda_s = \frac{w(X_0) - p_E\gamma_E}{X_0 w'(X_0)(dX/dx_E)|_{x_E=0} - (w(X_0) - p_E\gamma_E)}.$$

These results can be summed up as follows:

Proposition 2 *If $\lambda > \lambda_s$, x_E^* implicitly defined by (3) is strictly positive and we have:*

- *If $x_E^* > Q/\gamma_E$, the biofuel constraint is slack and it is optimal to produce energy crops up to x_E^*.*

- *Conversely, if $Q/\gamma_E > x_E^*$, the biofuel constraint is binding, but the objective of reaching Q is not as expensive as it could first appear: up to the quantity x_E^*, the biofuel program allows the government to lower the direct payments given to farmers, which in turns reduces the distortions linked to taxation. Hence, the real cost of the environmental program ought to be calculated only on the residual quantity of energy crops: $Q/\gamma_E - x_E^*$.*

Consequently, when the shadow cost of public funds is large, the regulator ought to implement a biofuel program for the reason that transferring income from the food sector to the farmers allows him to reduce the social cost of the farmer's income support policy. In order to give a hint on the value of λ_s, consider the rapeseed production in the EU-15. With a price elasticity of the agricultural crop supply equal to 0.28 (see the FAPRI elasticity database), $p_E\gamma_E/w(X_0) = 0.5$ and a 10% decrease in the consumption of rapeseed by the food industry, i.e. $(dx_F/dx_E)|_{x_E=0} = -0.1$, we have $\lambda_s = 0.18$. This value is smaller than the lower bound of the range of λ given in the literature (0.2 to 0.6). Therefore, a strictly positive quantity of biodiesel ought to be produced in the EU-15, on pure redistributive grounds.

The results of this section are limited to quantity produced domestically. However, buying energy crop on the world market could prove less expensive for society. We discuss in the next section the limit until which domestic production ought to take place.

3 Importation of energy crops

Consider now that the energy firm may also buy its raw material on the world market. Let X_E be the total quantity of energy crops, $X_E = x_E + x_I$, where x_E is the domestic energy crop and x_I the imported one, bought on the world market at price $\overline{w}$ from a perfectly elastic supply. Assume that $w(X_0) < \overline{w}$ and define X_N as the quantity of domestic energy crop such that $w(X_N) = \overline{w}$. The subsidies awarded by the regulator to the biofuel sector are $\sigma_E = w(X)/\gamma_E - p_E$ for the domestic energy crops, and $\sigma_I = \overline{w}/\gamma_E - p_E$ for the imported energy crops. The biofuel subsidy is thus given by $T = \gamma_E(\sigma_E x_E + \sigma_I x_I)$ and the regulator program is now given by:

$$\max_{x_E, x_I}\{W = \overline{\Pi}_A + CS + \Pi_F - (1+\lambda)(T + \overline{\Pi}_A - \Pi_A) + B(x_E + x_I) : x_E + x_I \geq Q/\gamma_E\}$$

Neglecting the biofuel production constraint ($Q = 0$), the optimal choices of the government must satisfy the following first-order conditions:

$$\lambda x_F w'(X)\frac{dX}{dx_E} - (1+\lambda)\{w(X) - p_E\gamma_E\} + q \leq 0 \qquad (x_E^* \geq 0) \qquad (4)$$

and

$$-(1+\lambda)(\overline{w}-p_E\gamma_E)+q\leq 0 \qquad (x_I^*\geq 0). \tag{5}$$

The latter condition states that (absent any constraint on the biofuel production), the optimal imported crop level equates the marginal social cost of subsidizing the biofuel industry with the marginal environmental benefit of biofuel. If q is large, it is optimal to import as much agricultural commodity as possible because of the positive GHG mitigation effects. We assumed that it is not case and consequently that we have $x_I^*=0$ when the biofuel constraint is not binding. Compared to (5), condition (4) entails the marginal social gain of the transfer of revenue from the food sector to the farmers, which eases the condition for a positive level of domestic biofuel crops. As long as $w(X)<\overline{w}$, the implications are thus the same as those obtained in the case of a closed economy. When X exceeds threshold X_N, it might be optimal to produce a domestic quantity such that the domestic price is greater than the world price. Indeed, we have $x_E^*>X_N-x_F$ if $(\partial W/\partial x_E)|_{X=X_N}>0$, which is effectively the case when $\lambda>\lambda_N$ given by

$$\lambda_N=\frac{\bar{w}-p_E\gamma_E-q}{X_Nw'(X_N)(dX/dx_E)|_{X=X_N}-(\bar{w}-p_E\gamma_E)}$$

Hence, when $Q/\gamma_E<x_E^*$, it is optimal to go beyond Q/γ_E and all the energy crops are produced domestically. In the case of a binding biofuel production constraint, $Q/\gamma_E>x_E^*$, energy crops produced domestically exceed level x_E^*. Indeed, when the biofuel constraint is binding, we can substitute Q/γ_E-x_E for x_I in the government program and the first-order condition for x_E becomes

$$\lambda x_Fw'(x_F+\hat{x}_E)\,(dX/dx_E)_{x_E=\hat{x}_E}-(1+\lambda)[w(x_F+\hat{x}_E)-\overline{w}]=0 \tag{6}$$

which implicitly defined $\hat{x}_E$. Plugging $x_E=\hat{x_E}$ in (4) and using (6) to substitute for the first term, we get:

$$(1+\lambda)[w(x_F+\hat{x}_E)-\overline{w}]+q-(1+\lambda)[w(x_F+\hat{x}_E)-p_E\gamma_E]=-(1+\lambda)(\overline{w}-p_E\gamma_E)+q<0$$

which implies that $\hat{x}_E>x_E^*$. Hence, taking into account imports, we have the following results:

Proposition 3 *If $\lambda>\lambda_N$, x_E^* implicitly defined by (3) is strictly positive and we have:*

- *If $x_E^*>Q/\gamma_E$, the biofuel constraint is slack and it is optimal to produce energy crops up to x_E^*.*

- *Conversely, if* $Q/\gamma_E > x_E^*$*, the biofuel constraint is binding, and it is optimal to produce energy crops domestically at level* $\hat{x}_E > x_E^*$ *implicitly defined by (6). Importations of raw materials are given by* $x_I^* = Q/\gamma_E - \hat{x}_E$.

- *The internal price of the agricultural feedstock verifies* $w(X) > \bar{w}$ *leading to subsidies* $\sigma_E > \sigma_I$.

4 Environmental policies and biofuel production

The important increase in the areas devoted to energy crop production could have major consequences on the environmental policies directed to agriculture. The EU Commission (2006b) notes that "the general use of chemicals could go up on the overall crop area if the increased demand for agricultural biomass cannot be met otherwise, in particular in the short to medium term." In the EU, the main environmental issues raised by agricultural feedstock production concern nitrates and pesticides. Dating back from 1991, the nitrates directive mandates Member States to set up a framework to monitor water quality related to agriculture and imposes a standard of 50 mg/l of nitrates in ground water.[6] As for pesticides, their use is regulated by EU directives aiming at controlling the way pesticides are marketed and the level of residues in food. Moreover, the water directive of 2000 imposes measures to reduce significantly discharges and losses of dangerous substances, in order to protect surface water.

In this section we extend our framework to account for the environmental externalities of the production of biofuel feedstock and in particular, the enforcement of agricultural environmental policies. The environmental implications of agricultural production are summarized in environmental damage function $D(\bar{e})$, where $\bar{e}$ is the environmental standard, with $D'(\bar{e}) > 0$, i.e., the larger the government allowances, the larger the environmental damages. The agricultural production process is affected by the standard: the lower the standard, the larger the marginal production cost. Denoting by $C(X, e)$ the cost function of the representative farm, where e is the level chosen by the farmer (which may be different from the standard $\bar{e}$) we thus have $C_{Xe} < 0$. We also assume that C is convex, i.e., that we have $C_{XX} > 0, C_{ee} > 0$ and $C_{XX}C_{ee} - C_{Xe}^2 > 0$. In the following, we discuss the problem of defining the environmental standard considering the enforcement issue of such a policy

[6] In addition, this directive requires each state to define "vulnerable zones" for which the quantity of nitrate must be limited to 170kg/ha/year.

in a framework similar to Malik (1992). Indeed, to enforce a demanding policy it is necessary for the State to control farms frequently and to be able to inflict sizeable penalties. We shall analyze this problem considering that controlling farms is costly and that the government inflict penalties that depends on the extend of the infringement. We analyze the two cases of a fix maximal penalty, and of a maximal penalty which corresponds to the farmers decoupled payment, as it is the case in the EU. We do not consider importations in this section.

4.1 The benchmark case

Let us first characterize the situation of a costless enforcement in which the farmers follow the environmental prescription (we shall discuss the enforcement problem shortly). Profit maximization of the representative farmer with respect to X defines the inverse supply function $w(X, \bar{e}) = C_X(X, \bar{e})$. As above, the equilibrium condition on the input market leads to an optimal demand of the agricultural raw product satisfying

$$g(x_F, x_E, \bar{e}) = ap_F(y_F)y_F/x_F - C_X(x_F + x_E, \bar{e}) \equiv 0 \tag{7}$$

The regulator chooses the optimal quantity of energy crops and the optimal level of environmental standard $\bar{e}$. Neglecting the constraint on the biofuel production, the agency program can thus be written as:

$$\max_{x_E, x_F, \bar{e}} \{\overline{\Pi}_A + CS + \Pi_F - (1+\lambda)[(C_X - p_E\gamma_E)x_E + \overline{\Pi}_A - \Pi_A] + B(x_E) - D(\bar{e}) : (7)\}$$

The corresponding Lagrangian is given by:

$$\mathcal{L} = CS + \Pi_F - (1+\lambda)[(C_X - p_E\gamma_E)x_E + \overline{\Pi}_A - \Pi] + B(x_E) - D(\bar{e}) - \beta[g(x_F, x_E, \bar{e})]$$

where β and τ are the multiplier corresponding to market equilibrium condition (7) and biofuel production constraint Q respectively, and we have $\tau \geq 0$ at the optimum of the agency program (with $\tau = 0$ when the biofuel constraint is lenient.) The optimal policy satisfies the following first-order conditions:

$$\frac{\partial \mathcal{L}}{\partial x_F} = \lambda x_F C_{XX} - \beta(\partial g/\partial x_F) = 0$$

$$\frac{\partial \mathcal{L}}{\partial x_E} = \lambda x_F C_{XX} - (1+\lambda)[C_X - p_E\gamma_E] + q - \beta\,(\partial g/\partial x_E)$$

and.

$$\frac{\partial \mathcal{L}}{\partial \bar{e}} = \lambda x_F C_{XE} - (1+\lambda)C_e - D'(\bar{e}) - \beta\,(\partial g/\partial \bar{e})\,.$$

Solving these equations for $\bar{e}, x_E$ and x_F leads to the following result:

Proposition 4 *If $\lambda > \lambda_s$, and $Q = 0$, the optimal policy $\bar{e}^*, x_E^*$ and x_F^* is implicitly defined by*

$$(1+\lambda)[C_X - p_E\gamma_E] - q = \lambda x_F C_{XX} dX/dx_E = -\frac{C_{XX}}{C_{Xe}}\{-(1+\lambda)C_e - D'(\bar{e})\} \quad (8)$$

The first equality corresponds to (3) in this framework. The last term of (8) corresponds to the marginal social surplus of agricultural production under standard $\bar{e}$: $D'(\bar{e})$ is the marginal damage and $-C_e$ the marginal reduction in production cost which corresponds to a social benefit $-(1+\lambda)C_e$ in public funds. The Pigovian rule calls for an environmental standard that nullifies this surplus. The first term of (8) corresponds the marginal social surplus of biofuel production, with the marginal social loss of subsidizing the biofuel sector given by $(1+\lambda)[C_X - p_E\gamma_E]$ and the value of the social benefit of GHG mitigation by q. The Pigovian level also requires that this marginal surplus is null. However, we know from (3) that this marginal surplus is equal to marginal social gain of the transfer of revenue from the food sector to farmers, which is positive whenever $\lambda > 0$. Hence, with a positive social cost of public funds, the marginal damage of agricultural production is lower than its social benefit, implying that the optimal standard $\bar{e}^*$ is lower than the Pigovian level. This can be easily understood: by setting a stringent environmental standard, the regulator increases the marginal cost of production (we have $C_{xe} < 0$) hence the price of the agricultural feedstock which reinforces the substitution effect between the biofuel subsidy policy and the farm support program.

4.2 Policy enforcement and cross-compliance

Stringent agricultural standards raise the problem of enforcing such environmental policies. Assume that facing a chosen pollution level e that exceed the standard $\bar{e}$, the agency is able to inflict a penalty that depends on the extent of the farmer infringement, $e - \bar{e}$, and more precisely that the corresponding penalty is a fraction $f(e - \bar{e}) \in [0, 1]$ of a maximal penalty Ψ. The function $f(\cdot)$ is exogenously given (by an independent legislative body) and is assumed increasing and convex in $e - \bar{e}$, with $f(0) = 0$. The maximal penalty can be either a given amount ($\bar{P}$), or the decoupled payment that the farmer should receive in case of compliance, $\overline{\Pi}_A - \Pi_A(X, \bar{e})$. The latter case corresponds to the current framework chosen by the EU to enforce environmental policies in agriculture. Let k be the probability of being controlled, and μk the corresponding cost.

The representative farmer faces the following maximization program.

$$\max_{X,e} wX - C(X, e) - kf(e - \bar{e})\Psi$$

and the maximization with respect to the level of pollution gives an optimal level e^* which satisfies

$$-C_e(X,e^*) - kf'(e^* - \bar{e})\Psi \leqslant 0$$

i.e., the marginal cost reduction from pollution must be lower than (or equal) to the marginal expected penalty. Since there is no social benefit associated to the payment of fines, we have $e^* = \bar{e}$ at the optimum of the government's program: no fine is paid in equilibrium. Moreover, as controlling farms is costly, this condition is binding at the optimum of the agency program, i.e. we have

$$-C_e(X,\bar{e}) - kf'(0)\Psi = 0 \tag{IC}$$

The agency simultaneously chooses the optimal level of control, the environmental standard and the scope of the biofuel program by maximizing

$$\max_{x_E,x_F,k,\bar{e}} \{\overline{\Pi}_A + CS + \Pi_F - (1+\lambda)[(C_X - p_E\gamma_E)x_E + \overline{\Pi}_A - \Pi_A + \mu k] + B(x_E) - D(\bar{e}) : (IC),(7)\}$$

Assuming an interior solution for the biofuel level, we have the following result:

Proposition 5 *Taking account of the cost of control, the optimal (unconstrained) policies verify:*

- In the case of a fix maximal penalty ($\Psi = \bar{P}$),

$$(1+\lambda)[C_X - p_E\gamma_E] - q = \left[\lambda x_F C_{XX} - (1+\lambda)\mu k \frac{C_{Xe}}{C_e}\right]\frac{dX}{dx_E}$$
$$= -\frac{C_{XX}}{C_{Xe}}\left\{-D'(\bar{e}) - (1+\lambda)C_e - (1+\lambda)\mu k(C_{ee} - C_{eX}^2/C_{XX})/C_e\right\}$$

  assuming that the optimal policy $\bar{e}^f, x_E^f$ and x_F^f is such that $x_E^f > 0$.

- In the case of cross-compliance provisions ($\Psi = \overline{\Pi}_A - \Pi_A$),

$$(1+\lambda)[C_X - p_E\gamma_E] - q = \left[\lambda x_F C_{XX} - (1+\lambda)\mu k \frac{C_{Xe} - kf'(0)XC_{XX}}{C_e}\right]\frac{dX}{dx_E}$$
$$= -\frac{C_{XX}}{C_{Xe}}\left\{-D'(\bar{e}) - (1+\lambda)C_e - (1+\lambda)\mu k(C_{ee} - C_{eX}^2/C_{XX} + kf'(0)C_e)/C_e\right\}$$

  assuming that the optimal policy $\bar{e}^{cc}, x_E^{cc}$ and x_F^{cc} is such that $x_E^{cc} > 0$.

- We have $\bar{e}^f > \bar{e}^*$ and $x_E^{cc} < x_E^f < x_E^*$.

Compared to the benchmark case, the cost of controls introduces distortions in the agency's trade-offs, which result in lower biofuels (unconstrained) production levels and environmental standards. However, the distortion on the production side is lower with a fix penalty than under cross-compliance provisions.

References

[1] Babcock, B. (2006). Farm Policy amid high prices: which direction will we take?, *Iowa Ag Review*, Vol.12, No4.

[2] Bontems, P. and Rotillon, G. (2003. L'économie de l'environnement, Repéres-La Découverte.

[3] Bloomberg (2006), Ethanol frenzy, *Bloomberg Markets*, July, 78-86.

[4] Center for Science in the Public Interest (2006), Cruel Oil. How palm oil harms health, rainforest and wildlife.

[5] Confederation of the food and drink industries of the EU (2006). CIAA position on the EU biofuels strategy proposed by the Commission, April.

[6] Commission of the European Communities (2006), An EU Strategy for Biofuels, Communication from the Commission.

[7] Commission of the European Communities (2006), An EU Strategy for Biofuels- Impact Assessment, Communication from the Commission.

[8] Dronne, Y. and Gohin, A. (2006). Le développement des utilisations non alimentaires de l'huile de colza dans l'UE: quels impacts sur les marchés et prix mondiaux, *OCL*, vol. 12, n.5-6, Septembre-Décembre.

[9] Elobeid, A. and Tokgoz, S. (2006). Removal of U.S. Ethanol Domestic and Trade Distortions: Impact on U.S. and Brazilian Ethanol Markets, *FAPRI Working Paper*, 06-WP 427, August.

[10] Elobeid, A. et al. (2006). The long-run impact of corn-based ethanol on the grain, oilseed, and livestock sectors: a preliminary assessement, *CARD Briefing Paper*, 06-BP 49, November.
Financial Times, Rising biofuel demand pushes up crop prices, www.ft.com, accessed July 2006.

[11] Forbes, Unilever's Jope warns of biodiesel's downside, www.forbes.com, accessed July 8th 2006.
General Accounting Office (2003). Agricultural conservation: USDA needs to better ensure protection of highly erodible croplands and wetlands, GAO-03-418, Washington DC, April.

[12] Hart, C. (2006). Feeding the ethanol boom: where will the corn come from? , *Iowa Ag Review online*, Fall, vol.12 n°4.

[13] International Policy Council (2006), WTO disciplines and biofuels: opportunities and constraints in the creation of a global marketplace, October.

[14] Lubowski, R. et al. (2006). Environmental effects of agricultural land-use change, Economic Research Service, Economic Research Report Number 25, July.

[15] Malik, A. (1992). Enforcement costs and the choice of policy instruments for controlling pollution. *Economic Inquiry*, Vol. XXX, 714-721.
Marshall, L. and Greenhalgh, S. (2006). Beyond the RFS: the environmental and economic impacts of increased grain ethanol production in the U.S., WRI Policy Note, September.

[16] Schmidhuber, J. (2006). Competition between food and non food uses, presentation at the "Notre Europe" meeting, What future framework for Agricultural policies in Europe and Developing countries, Paris.

[17] Sourie, J.-C. et al. (2006). Economic impact of biofuel chains in France, Paper presented for the annual congress of the AAEA in Long Beach, July.

[18] Tokgoz, S. and Elobeid, A. (2006). An analysis of the link between ethanol, energy and crop markets, CARD Working Paper 06-WP 435, November.

[19] Unilever (2006). Unilever's contribution to: Review of EU Biofuels Directive, Public Consultation Exercise, April-July.