Impacts of Agri-environmental Policies on Land Allocation and Land Prices

University of Helsinki
Department of Economics and Management
Discussion Papers n:o 14
Environmental Economics
Helsinki 2006
Hervé Guyomard (*) , Jussi Lankoski (**) and Markku Ollikainen (***)

IMPACTS OF AGRI-ENVIRONMENTAL POLICIES ON LAND ALLOCATION
AND LAND PRICES

February 13, 2005
IMPACTS OF AGRI-ENVIRONMENTAL POLICIES ON LAND ALLOCATION
AND LAND PRICES

Abstract. We develop a Ricardian framework with heterogeneous land quality to analyse the effects of agricultural and agri-environmental support policies on land allocation decisions and land prices. Four agri-environmental policy instruments are considered: a uniform area payment, a quality-dependent area payment, a mandatory buffer strip policy and a voluntary buffer strip payment. We also analyse how general tax and monetary policies may affect agricultural land prices. The theoretical framework is illustrated by an empirical model applied to Finnish agriculture. The empirical model shows that macroeconomic factors, such as general tax and monetary policies, may exert a greater impact on land prices than some minor fine-tuning in agri-environmental policies.

Key words: agri-environmental policy, acreage subsidy, Ricardian rent, land price

JEL-classification: Q11, Q18
1. Introduction

Government intervention is still pervasive in agriculture. The different ways governments intervene to achieve one or several objectives are clearly not equivalent because some types of policy instruments are more efficient and/or less production and trade distorting than others. Policy instruments may affect output supplies, input use intensities and land allocation. Even decoupled instruments may entail some or all of these effects. As a result, it is important to closely examine which types of effects each policy instrument causes.

Using a static and riskless single-output partial equilibrium model of the farm sector, Hertel (1989) compares the impacts on production, exports, input demands, consumption prices, and land prices of export, output and variable input subsidies that have equal cost or deliver equal support to farmers. Within this framework where land supply is imperfectly elastic, the production and trade effects of output payments are shown to be lower than those of export and input subsidies, provided the subsidised input and land are substitutes. Dewbre et al. (2001) use a similar framework to compare the production, trade and income effects of four policy instruments (market price support, output subsidy, area payment and a subsidy on purchased inputs). Payments based on land use are shown to be the most efficient, followed by output subsidies, market price support and subsidies based on purchased inputs. The ranking of production and trade distortion effects is just the reverse, with payments based on purchased inputs being the most distorting.

In this paper, we develop a static and riskless Ricardian model of heterogeneous land
quality. Within this framework, we analyse the effects of agricultural and agri-environmental policies on land allocation decisions and land prices. Our analysis is oriented to the Common Agricultural Policy (CAP) in the European Union (EU). Therefore, the instruments retained aim to fit the main features of the current situation in the EU, in a similar vein to that of Guyomard et al. (2004), but is focused more on land prices. We examine the following three policy instruments: an area payment, a cross-compliance requirement represented by a payment conditional on a buffer strip of a predetermined size, and a payment granted to farmers for buffer strip sizes in excess of the minimum buffer strip area.

Farmland is valued for its productive component using the present value approach where the current value of a parcel is measured as the sum of the expected future cash flows discounted according to their respective risks (Goodwin et al., 2003). Some recent studies suggest that the present value model does not fully explain farmland values and prices. Other determining factors include a consumptive component (the intrinsic value of land to the owner), a speculative component and transaction costs (Tsoodle et al., 2003). However, results from Falk and Lee (1998) suggest that these other components essentially play a role in the short run, explaining land price deviations from the values implied by the present value model, while farmland prices return to the present value in the long run.

Our present value model is considerably simplified by assuming that the discount rate is the same for each source of returns (on this point see, for example, Weersink et al. (1998) or Goodwin et al. (2003) who attach different discount rates to return components
depending on their origin, i.e. market returns or government payments). In addition, the common discount rate is assumed constant over time. These assumptions are restrictive. However, our objective is not to assess the relationship between cash (i.e., uncapitalised) rents and land values. Instead, we wish to explain how agricultural and agri-environmental policies affect cash rents. A prediction about the direction of cash rents will be equivalent to a prediction about the direction of land prices under the assumption that policies influence farmland prices essentially through their impacts on cash rents.

2. Agri-environmental policies in a Ricardian framework

In this section, we outline the preliminary steps needed for the analysis of land price determination in a Ricardian model of heterogeneous land quality. These steps entail analyzing the production and land allocation decisions subject to policies. The three policy instruments we consider are:

(i) A crop area payment, $s$, which can alternatively be a fixed amount over all land qualities or be dependent on land quality. This instrument represents the CAP compensation payment for crop producers (compensation for reduced intervention price).

(ii) A buffer strip of a predetermined size, $m$, which is a precondition for obtaining crop area payments, representing in a simple and simplified way the cross-compliance requirement in the June 2003 reform of the CAP.

(iii) A buffer strip payment, $b(m)$, which is paid for the part of buffer strip exceeding the mandatory size. This buffer strip payment is assumed to decrease relative to the size of
the buffer strip. Specifically, we assume that the buffer strip payment, \( b(\hat{m}) \), is positive but decreasing for \( \hat{m} = m - m > 0 \), with \( b(\hat{m}) = 0 \) for \( \hat{m} = m - m = 0 \), i.e., for the mandatory buffer strip size. To characterize the comparative static nature of the buffer strip payment, we actually express it as \( \varepsilon b(\hat{m}) \) but normalize for most of the discussion \( \varepsilon \) to 1.

Under a policy package consisting of a combination of these instruments, the farmer has to choose the fertilizer application rate, the size of the buffer strip and the allocation of land between agricultural land uses. These decisions entail many possibilities. The farmer may not establish buffer strips at all and decline to receive crop area payments. He may also establish the mandatory buffer strip only to obtain the area payment, or a larger buffer strip to obtain additional voluntary buffer strip payments. These decisions depend on the agricultural production conditions on which we next focus but, drawing on previous literature, we can anticipate that larger buffer strips will most likely be established on lower quality parcels in agriculture (see, e.g., Lankoski and Ollikainen, 2003; Lankoski et al., 2004).

We assume that agricultural production is carried out under conditions of heterogeneous land quality. Land can be classified into parcels which are of the same size and homogeneous in quality. Land quality differs over parcels and we rank the land quality by a scalar measure, \( q \), with the scale chosen without loss of generality so that minimal land quality is zero and maximal land quality is one, i.e., \( 0 \leq q \leq 1 \) (Lichtenberg, 1989). Let \( G(q) \) denote the cumulative distribution of \( q \) (acreage having quality \( q \) at most), while \( g(q) \) is its density which is, by assumption, continuous and differentiable. The total
amount of land is thus

\[ G = \int_0^1 g(q) dq. \]  

(1)

For simplicity, suppose that there is only one representative cereal crop to capture the area allocated to crop production. Part of the land can naturally be allocated to other agricultural uses as well. These alternative agricultural uses are described by allowing land use for pasture or fallow. The cereal crop is produced under constant returns to scale technology on each parcel of quality \( q \). Agricultural output per unit of land area, \( y \), is a function of the fertilizer application rate, \( l \), and land quality, \( q \), i.e., \( y = f(l; q) \). The production function is increasing and concave in fertilizer and land quality, i.e.,

\[ f_l(l; q) > 0, \ f_{ll}(l; q) < 0, \ f_q(l; q) > 0, \ f_{qq}(l; q) < 0. \]

The revenue per unit of land area generated by other agricultural uses is denoted \( \pi^* \). For simplicity, we assume that this revenue is independent of soil quality.

### Analysis at the intensive margin

Let \( p \) and \( c \) denote the prices of the crop and fertilizer, respectively. We divide fixed costs per hectare into two classes, those that depend on the size of cultivated part of parcel \( I \) and those that do not \( F \). We can then express the profit function of a representative farmer for a parcel of quality \( q \) as follows

\[ \pi^A = (1 - \hat{m}) \left[ pf(l; q) - cl - I + s \right] + b(\hat{m}) - F. \]  

(2)

The solution to the maximization problem (2) may contain two types of parcels, those on
which only mandatory buffer strips are established and those on which larger buffer strips are implemented.

When voluntary buffer strip payments are absent, the profit function reduces to

$$\pi^A = (1 - \overline{m}) \left[ pf(l; q) - cl - l + s - F \right].$$

In the former equation (2), both fertilizer application and buffer strip size are decision variables. For the latter (2'), the only choice for the farmer is the amount of fertilizer to apply. In what follows, we analyze the farmer’s choice under (2). The simpler case of (2') can readily be derived from the more general analysis (2).

The first-order conditions characterizing the farmer’s optimal choices for (2) are

$$\pi^A_i = pf_i - c = 0,$$  \hfill (3a)

$$\pi^A_m = -pf(l; q) + cl + l - s + b' (\hat{m}) = 0.$$  \hfill (3b)

From (3a) and (3b), the fertilizer application rate and the buffer strip size should be chosen to equate marginal revenue with marginal costs. As shown elsewhere, the optimal fertilizer application rate and buffer strip size will vary across parcels due to differences in land quality (Lankoski and Ollikainen, 2003; Lankoski et al., 2004). On any given parcel, the comparative static of the exogenous parameters on the use of inputs can be condensed to
Increases in crop prices increase the fertilizer application rate and decrease the buffer strip size. Note that an increase in producer price support works like an increase in the crop price. Neither crop area payments nor buffer strip payments affect the fertilizer application rate, but they do affect the buffer strip size. Crop area payments decrease the buffer strip size while buffer strip payments increase it. Fixed costs that depend on the size of actually cultivated part of parcels \( I \) have no effect on fertilizer intensity, while they increase the buffer strip size. Costs independent of this size \( F \) are neutral both in terms of fertilizer use and buffer strip size.\(^2\)

If the policy entails a mandatory buffer strip only (or if the farmer declines to accept voluntary buffer strip payments for some parcels), then \((2')\) alone will characterize his economic decision. In that case, fertilizer application will depend positively on the crop price and negatively on the fertilizer costs, but not on area payments, the size of the mandatory buffer strip and the two types of fixed costs, i.e.,

\[
l = l(p, c, s, \varepsilon, I, F), \quad (4a)
\]

\[
\hat{m} = \hat{m}(p, c, s, \varepsilon, I, F). \quad (4b)
\]

These comparative static results show that crop area and buffer strip payments are decoupled from the fertilizer intensity on the cultivated land of quality \( q \) (equations 4a and 4c). However, they are not decoupled from the land parcel of this land quality as they have an impact on the size of the buffer strip (equation 4b).
Land allocation

Land allocation between crop production and other agricultural uses will depend on the chosen policy instruments. Let $L_A$ denote the share of land allocated to the crop and $L_F$ denote the share of land allocated to other agricultural uses. As total agricultural land is normalized to 1, we have $L_F = (1 - L_A)$. To obtain a solution where land is allocated to both uses, we assume that crop production yields higher profits than fallowing on high quality land and that the opposite holds for low quality land. As a result, the farmer maximizes his profit by allocating land according to its quality and the resulting rents between crop production and fallowing as follows

$$
\max_{L_A} \int_{0}^{1} \left[ \pi^* L_A + \pi^F (1 - L_A) \right] g(q) dq,
$$

where the stars indicate that profits are restricted. Profits correspond to the maximum rents obtainable on each land parcel subject to exogenous market and policy parameters. By differentiation, the condition characterizing the critical land quality, $q^*$, can be expressed as

$$
\pi^A(p, c, s, \varepsilon, I, F) = \pi^F.
$$

According to (6), the critical land quality, which defines land allocation between crop production and fallowing is obtained at the point where rents from each use are equal.
Above this land quality threshold, rents from crop production are higher than those from fallowing, and vice-versa. Clearly, the solution in (6) is a function of all exogenous variables. When these exogenous variables change, land allocations also change. From (6), the land area devoted to crop production can be expressed as

\[
H_A = \int_{q'}^{1} g(q)dq = G(1) - G(q^*). \tag{7}
\]

The effects of exogenous parameters on land devoted to crop production can be obtained by differentiating (7), accounting for the fact that the critical land quality is implicitly defined by (6). We express the effects of changes in any exogenous variable as

\[
\frac{\partial H_A}{\partial \theta} = -g(q^*)(\frac{\partial q^*}{\partial \theta}) \quad \text{where} \quad \theta \quad \text{is an element of the vector of all exogenous variables.}
\]

We first differentiate (6) to see how the critical land quality depends on the exogenous parameters. Therefore we solve for \( \frac{\partial q^*}{\partial \theta} \), to get

\[
\frac{\partial q^*}{\partial p} = -(\frac{\pi_q^A}{\pi_p^A}) < 0, \quad \frac{\partial q^*}{\partial c} = -(\frac{\pi_c^A}{\pi_q^A}) > 0, \\
\frac{\partial q^*}{\partial s} = -(\frac{\pi_s^A}{\pi_q^A}) \leq 0, \quad \frac{\partial q^*}{\partial \varepsilon} = -(\frac{\pi_{\varepsilon}^A}{\pi_q^A}) \leq 0, \\
\frac{\partial q^*}{\partial I} = -(\frac{\pi_I^A}{\pi_q^A}) > 0, \quad \frac{\partial q^*}{\partial F} = -(\frac{\pi_F^A}{\pi_q^A}) > 0, \tag{8}
\]

where \( \pi_q^A = pf_q > 0 \) is for the case of a uniform crop area payment and \( \pi_q^A = pf_q + s'(q) > 0 \) is for a quality dependent area payment. The remaining derivates are obtained from equation (2).
From (8), an increase in the crop price reduces the critical quality of land allocated to crop production while an increase in fertilizer prices increases this critical land quality. We also see that higher fixed costs, be they dependent on cultivated share of parcel (I) or not (F), increase the critical land quality.

Land allocation follows one-to-one changes in the critical land quality. We start with the market parameters, crop prices, fertilizer costs and fixed costs. We have

$$\frac{\partial H_A}{\partial p}>0, \frac{\partial H_A}{\partial c}<0, \frac{\partial H_A}{\partial I}<0, \frac{\partial H_A}{\partial F}<0. \quad (9a)$$

The effect of crop prices and fertilizer costs are as expected. Higher crop prices (fertilizer costs) shift the critical land quality to lower (higher) quality parcels and thus increase (decrease) land under crop production. Both types of fixed costs decrease the land allocated to crop production.

Policy parameters include crop area and buffer strip payments, as well as the mandatory buffer strip size. We obtain

$$\frac{\partial H_A}{\partial s}>0, \frac{\partial H_A}{\partial \epsilon}>0, \frac{\partial H_A}{\partial m}<0. \quad (9b)$$

The effects of crop area payments are particularly interesting. An increase in the uniform area payment - or a uniform increase in all quality dependent area payments - increases profitability over all parcels and as a result shifts the critical land quality to lower quality.
parcels. This, naturally, increases land area allocated to crop production. If the size of the
crop area payment depends on land quality, any increase in the area payment for a given
quality (but not for the others) will affect the critical land quality and land allocation only
if this increase takes place for the subsequent parcels just below the critical land quality.
An increase in the size of the mandatory buffer strip decreases land in crop production.
The reason is obvious. Rents from all parcels under crop production decrease as more
land is allocated out of production. Therefore, for some lower quality parcels, rents from
fallowing become higher and land is allocated for this purpose. A higher buffer strip
payment increases rents and thus shifts the critical land quality downwards and hence
increases land allocated to crop production.

In sum, in comparative static terms, land allocation is not decoupled at the extensive
margin with respect to crop area payments, the mandatory buffer strip size and voluntary
buffer strip payments. This feature has been shown to hold for area payments in
Lichtenberg (2002). This finding is now extended to buffer strip payments.

3. Crop land price determination

We are now in position to start our analysis of the determination of agricultural land
prices. To facilitate the analysis, we make the following additional assumptions. All
markets are perfect, all agents have perfect foresight, capital and labour are perfectly
mobile in the economy and earn fixed and competitive returns. Our time horizon is the
long run. Under these assumptions, our Ricardian framework provides a simple but
effective implicit model of land price determination.
In this model, the rent earned by the minimum quality of land equals the fixed rent earned in pasture or fallowing, $\pi^F$. Any land of higher quality earns a positive Ricardian crop rent equal to $\pi^A(q) - \pi^F$. By assumption, land supply for each quality is fixed. But land demand for each quality depends on crop rents. More specifically, every parcel which provides a positive crop rent is demanded for crop production. As a result, land demand is positive for all parcels yielding zero or positive crop rents. The marginal willingness to pay for crop land equals that of other agricultural uses at the critical land quality $q^*$. Below this threshold, the marginal willingness to pay for crop land falls short of that for pasturing and fallowing.

What this means is simply that under a fixed supply of land, the demand for this land is the sole determinant of the price of crop land (see, e.g., Palmquist, 1989). Demand in turn is defined by the rents derived from crop production. Hence, the price of crop land of any quality $q$ can be defined as the sum of the intertemporal services it provides. In crop production, this simply means the present value sum of the rents it provides over an infinite time horizon. Denoting the price of land of quality $q$ by $P(q)$, we thus have

$$P(q) = \int_0^\infty \pi(q)e^{-rt}dt = \frac{\pi^A(q)}{r}, \quad (10)$$

where $r$ is the discount rate.

From (10), we now analyze how exogenous parameters affect the price of crop land of quality $q$. We start with the market instruments, crop prices $p$ and fertilizer unit costs $c$. 
Differentiating (10) with respect to $p$ and $c$, and invoking the envelope theorem, yields

$$
\frac{dP(q)}{dp} = \frac{\pi_p^A}{r} > 0, \quad \frac{dP(q)}{dc} = \frac{\pi_c^A}{r} < 0.
$$

(11)

Results are as expected. Higher crop prices make crop production more profitable over all parcels and hence increase the price of land of each quality allocated to crop production. Higher fertilizer costs have the opposite effect.

We continue by analysing the agri-environmental policy parameters. Let us first consider crop area payments. Recall that we allowed either for a uniform or quality-dependent area payment. In the case of quality-dependent area payments, we must distinguish between the own effect of $s(q)$ and cross-effects of $s(\hat{q})$ on the price of land of quality $q$.

Differentiating (10) with respect to $s$ under these alternative formulations yields

$$
\frac{dP(q)}{ds} = \frac{\pi_s^A}{r} > 0, \quad \frac{dP(q)}{ds(q)} = \frac{\pi_{s(q)}^A}{r} > 0, \quad \frac{dP(q)}{ds(\hat{q})} = \frac{\pi_{s(\hat{q})}^A}{r} = 0.
$$

(12)

From (12), an increase in the uniform area payment increases the land price for all crop land qualities. While an increase in the area payment dependent on quality $q$ increases the price of this land quality, a higher area payment dependent on quality $\hat{q} \neq q$ has no effect on the land price of quality $q$.

For the effects of a mandatory buffer strip and buffer strip payments, we obtain
According to (13), a higher buffer strip norm decreases the price of crop land while
buffer strip payments increase the price of those qualities where larger buffer strips are
profitable.

Overall, the results can be summarised by the following proposition:

**Proposition 1. Agri-environmental determinants of crop land prices.**
Under heterogeneous land quality, perfect markets and perfect foresight, crop land prices
vary across land qualities and depend on market parameters and policy instruments.
While higher crop prices, crop area and buffer strip payments generally increase land
prices, higher fertilizer costs and higher mandatory buffer strip sizes decrease it.

The effects of market parameters are obvious. Interestingly, higher area payments,
although neutral in terms of production intensities, have the effect of providing higher
rents and thereby of increasing crop land prices. Mandatory buffer strips have the
opposing effect and they decrease land prices.

In Corollary 1 we characterize how area payments capitalize into land prices

**Corollary 1.**
Area payments increase agricultural land prices in all qualities. For the degree of
capitalization of area payments in land prices, the following holds:

a) the smaller the change in land allocation, the higher the capitalization rate of
area payments on land prices,

b) the more elastic the supply of inputs and the more elastic demand for the output, the higher the capitalization rate irrespective of the change in land allocation.

Let us next ask whether uniform versus quality-dependent area payments affect crop land prices differently, or not. This is an important issue since the main purpose of agricultural and agri-environmental policies is to support farm incomes and to address agri-environmental externalities rather than increase the value of farm assets through the capitalization of support into land prices. Our answer to this question is given in the following corollary.

**Corollary 2.**
For all parcels where the uniform area payment is smaller than the quality dependent area payment, an increase in the uniform payment will induce a smaller effect on land prices than the quality dependent payment, and vice-versa.

**Proof.**
Consider any parcel \( j \). Let \( s > s(j) \). Then, for this parcel, \( \pi^u[s] > \pi^q[s(j)] \). Conversely, if \( s < s(j) \), then \( \pi^u[s] < \pi^q[s(j)] \).

Corollary 1 has important implications. Quality dependent area payments will increase the price of high quality lands more than will a uniform payment. This might be viewed as an argument in favour of uniform payments.

We finally investigate how general tax and monetary policy affects crop land prices.
Suppose that the tax authorities levy a tax, $t$, on farm income with full tax deductibility of costs incurred. In economic terms, this type of tax functions like a profit tax, i.e., a tax on the rent from agriculture. It is thus neutral in terms of agricultural production decision.\(^4\)

As is well known, adjusting the interest rate is one of the basic means of monetary policy. For this purpose, we denote the discretionary policy parameter of the central bank by $d$. Accordingly we have $r = r(d)$. Moreover, we assume that $r'(d) > 0$. By increasing its market operations, the central bank can increase the interest rate level, and vice-versa.

Under these assumptions, the after-tax land price defined by our model becomes

$$\hat{P}(q) = \int_0^\infty (1-t)\pi(q)e^{-r(d)t}dt = \frac{(1-t)\pi^\lambda(q)}{r(d)}.$$  \hspace{1cm} (14)

Differentiating (14) with respect to $t$, $r$ and $d$ yields

$$\frac{d\hat{P}(q)}{dt} = -\frac{\pi^\lambda}{r} < 0, \quad \frac{d\hat{P}(q)}{dr} = -\frac{(1-t)\pi^\lambda}{r^2} < 0, \quad \frac{d\hat{P}(q)}{dd} = -\frac{r'(1-t)\pi^\lambda}{r^2} < 0.$$  \hspace{1cm} (15)

The effects are as expected. Higher profit taxes decrease land prices and so do higher real interest rates. A discretionary policy of higher interest rates has a similar effect, indicating that a lower interest rate policy increases land prices. In sum, we have

**Proposition 2. Effects of macroeconomic policy parameters on land prices.**

Land prices are subject to general monetary and tax policies. These policies affect prices of each land quality in a similar fashion. Higher profit taxes and interest rates decrease land prices over all qualities. Discretionary monetary policy towards higher (lower) real interest rates decreases (increases) land prices over all qualities.

Proposition 2 is important in showing that not only agri-environmental parameters
determine land prices but also general macroeconomic policy parameters. It would be interesting to assess empirically the relative weights of these two types of parameters on land price levels. In the next section, we provide an answer to this question on the basis of an illustration for Finnish agriculture.\(^5\)

4. Empirical application to Finnish agriculture

We now apply our theoretical framework to Finnish agriculture. To that end, we build a parametric model of agricultural production and land price determination for crop production in Southern and South-Western Finland. Production data are from studies performed on clay soils in this region on which almost all Finnish wheat is produced. Prices, costs and subsidies are for the year 2003. In addition to fertilizer costs, other variable costs (such as seeds, plant protection, fuel, etc.) of cultivation are included, as well as labour and machinery costs (machinery costs include depreciation, maintenance, insurance and interest charges). The model is used to estimate input use, land allocation, production, profits and land prices under several policy environments.

4.1 A parametric model of wheat production

The profit earned from growing wheat on any given production unit is given by

\[
\pi_i = (1-\hat{m})[p\alpha(1-\gamma e^{-\beta_i})-c(\chi-\phi+s)-k+(\lambda-0.5\omega\hat{m}_i)\hat{m}_i] \quad \text{for } i = 1, \ldots, 20. \quad (16)
\]

where \((\lambda-0.5\omega\hat{m}_i)\hat{m}_i\) is the buffer strip payment, \(\chi\) represents expenditures per hectare
for all variable inputs except fertilizers, $\varphi$ are labour costs per hectare and $k$ are machinery costs per hectare. We use the Mitscherlich nitrogen response function for wheat, i.e., $y = \alpha(1 - \gamma e^{-\beta I})$, where $y$ is yield per hectare, $l$ is nitrogen use per hectare, and $\alpha$, $\beta$ and $\gamma$ are parameters. Land quality is incorporated through the parameter $\alpha$ in order to calibrate the nitrogen response function to actual yield levels corresponding to a given fertilizer use in Southern and South-Western Finland. Land quality is assumed to be uniformly distributed with a minimum quality set to reflect the quality of typical set-aside land allocated to long-term fallowing. The parameter $\alpha$ is assumed to be linear in land quality, i.e., $\alpha = \mu_0 + \mu_1 q$. The model contains 20 production units of differential land quality. The parameter values used in the simulations are reported in Appendix 1.

Policy experiments are described in Table 1. Reflecting our theoretical model, we include both versions of crop area payments, i.e., uniform and quality-dependent area payments. Both area payment policies can be modified by combining them with cross-compliance requirements. In our case, this cross-compliance requirement is defined by a mandatory buffer strip policy. All these assumptions define the four policy experiments reported in Table 1.

(Insert Table 1)

The alternative to crop cultivation is fallowing arable land. Fallow land is entitled to a CAP compensation payment (€ 207 per hectare) and LFA (Less Favoured Area) support (€ 150 per hectare). Given that the costs of establishment and management are € 35 per hectare, the fixed net return to fallow is € 322 per hectare.
4.2. Empirical results

We report our results in three stages. We start with the case where only uniform and quality-dependent area payments are paid, or are combined with the mandatory buffer strip requirements (Tables 2 and 3). We then discuss the case where voluntary buffer strip payments are offered in addition to the mandatory buffer strips (Tables 4 and 5). We finally report the effects of general tax policy (Table 6).

Area payment and mandatory buffer strips

Following our theoretical analysis, we start with the “preliminaries” and in Table 2 bring together in summary form the effects of the four policy experiments on fertilizer use per parcel, buffer strip size, land allocation, total wheat production, per-hectare profits for wheat cultivation and total profits including the return to fallow land, and finally budget costs. For per-hectare fertilizer use and profit, we present both the mean values and the spread.

(Insert Table 2)

Policy experiment 1 assumes a uniform area payment of € 524 per hectare. It results in the allocation of 16 hectares to wheat production and 4 hectares to fallow. For a budget cost of € 9812, total profits (wheat cultivation and fallow) amount to € 7168. Per-hectare wheat profits range between € 327 and € 408, with an average value of € 368.
Policy experiment 2 assumes that the area payment is an increasing function of land quality, the highest (lowest) quality land receiving a payment of € 582 per hectare (€ 472 per hectare). This second experiment decreases the number of parcels allocated to wheat by 3 units, which increases the number of fallow parcels by the same amount. Total wheat production is significantly reduced, by more than 17 %, due to the reduction in wheat area. For a budget cost of € 9614, total farm profits amount to € 7439. Relative to the first experiment, this second one increases total profits by 3.8 % and decreases budget costs by 2 %. The transfer efficiency (the ratio of the change in profits to the change in support payments) of the quality-dependent area payment policy is 0.77 compared to 0.73 for the uniform area payment policy.

Policy experiments 3 and 4 introduce cross compliance requirements under the form of a mandatory three-metre-wide buffer strip. In the case where the area payment does not depend on land quality, this requirement leads to an increase in wheat production as a result of the increase in the cultivated area of wheat (experiment 3 relative to 1). This result may seem counterintuitive. Why would a reduction in wheat yields increase the profitability of wheat cultivation? In practice, this result is an illustration of production in extreme agricultural conditions where, in the absence of support payments, agricultural profits are negative on the lowest quality parcels. In these circumstances, only support payments make agriculture profitable. Under negative “operational profits” and low productivity, introducing a mandatory buffer strip as a cross-compliance requirement reduces cultivated share dependent costs ($J$) more than the value of production decreases.\textsuperscript{6} This makes the “operational profits” less negative and overall profits more positive so that an additional parcel is allocated to wheat production (experiment 3 relative to 1).\textsuperscript{7} By
contrast, when the area payment is an increasing function of land quality, introducing mandatory buffer strips as a cross-compliance requirement does not change the wheat and fallow area. As a result, wheat production slightly decreases due to the mandatory buffer strips (experiment 4 relative to 2).

These contrasting results highlight the importance of taking into account the whole set of policy instruments and not of each instrument separately. Moreover, policy instruments may produce perverse incentives for marginal low quality land. If we compare experiments 1 and 3, we note that the cross-compliance requirement reduces the transfer efficiency of the policy since total profits decrease while budget costs increase (the transfer efficiency of experiment 3 is 0.72). In the case of experiments 2 and 4, the cross-compliance requirement also slightly decreases the transfer efficiency of the policy since total profits decrease for an unchanged budget cost. But this transfer efficiency measure does not include net environmental effects of the buffer strip that are likely to be positive.

We next examine the effects of the four policy experiments on agricultural land prices. Table 3 presents the impacts of the four policy experiments on pre-tax land prices (column two) and their comparative statics, i.e., land price changes in reaction to a 10% increase in, respectively, wheat prices, fertilizer costs, uniform area payments and land quality dependent area payments (column three to six).

(Insert Table 3)

Table 3 shows how the four policy experiments affect pre-tax land prices. It is
immediately obvious that these prices always increase with land quality, for a given policy experiment. We also note that they are higher in experiments 2 and 4 where the area payment depends on land quality (and here is assumed to increase with the land quality index) than in experiments 1 and 3 where the area payment does not depend on land quality. This result shows that the crop area payment is capitalised into land prices. Let us, for example, consider land prices for the highest land quality in experiments 1 and 2. In experiment 1, the highest quality land price is € 8164 per hectare for a payment of € 524 per hectare. In experiment 2, the highest quality land price is € 9327 per hectare for a payment of € 582 per hectare. These figures show that an increase in an area payment of 11 % leads to an increase in land prices of 14.2 %. Table 3 also illustrates Proposition 1 - that land prices increase with wheat prices and area payments, and decrease with input (fertilizer) costs.

**Voluntary buffer strip payments**

We now turn to the case of voluntary buffer strip payments. These payments are combined with policy experiments 3 or 4. From (20), recall that this payment takes the form \( b(m) = (\lambda - 0.5 \omega m) \hat{m} \). Under our parameter values, the number of parcels in wheat production with voluntary buffer strips depends on the policy scheme. Under uniform area payments in policy experiment 3bis, voluntary buffer strips are established on the six lowest quality parcels. Under quality-dependent area payments in policy experiment 4bis, voluntary buffer strips are established only on the three lowest quality parcels. The average share of voluntary buffer strips is 0.063 (with a range 0.102 - 0.025) with experiment 3bis and 0.074 (0.107 - 0.042) with experiment 4bis. The average buffer strip payment paid for the established voluntary buffer strip is € 17.5 (with a range € 31.2 - €
3.6) for experiment 3bis, and € 21.5 (with a range € 33.0 - € 9.9) for experiment 4bis.

Table 4 summarizes the effects of introducing voluntary buffer strip payments on fertilizer use per hectare, land allocation, wheat production, per-hectare and total profits, as well as budget costs. Comparing Tables 4 and 2 reveals the key differences. First, note that the average sizes of buffer strips are higher in experiments 3bis and 4bis relative to experiments 3 and 4, respectively. Land allocation does not change in experiment 3bis relative to 3. But due to the increased buffer strip size, average fertilizer use decreases. Wheat production decreases too. Per-hectare and total profits are practically unchanged as are budget costs. The number of parcels allocated to wheat production increases by one unit in experiment 4bis relative to 4. This leads to an increase in wheat production although the average size of buffer strips increases. Per-hectare profits are (slightly) lower but total profits are practically unchanged. Budget costs increase from € 9614 in experiment 4 to € 9763 in experiment 4bis.

(Insert Table 4)

Table 5 illustrates how land prices react when voluntary buffer strip payment is introduced. However, comparing Tables 5 and 4, we can see that the differences are negligible. Land prices are slightly higher in experiment 3bis (respectively 4bis) relative to 3 (4).

(Insert Table 5)
General tax policies

The final set of results shown in Table 6 deals with the effects of general tax and monetary policies on agricultural land prices. The second column of this table defines the after-tax land price in the reference situation while the next two columns present the effect of changes in the tax and discount rates, respectively.

(Insert Table 6)

Relative to Table 3, we note that the tax applied to agricultural net revenue effectively decreases land prices. In accordance with Proposition 2, we also observe that increases in profit taxes (column three) or interest rates (column four) decrease land prices. Interestingly, we find that an increase in taxes from 25 to 35 % of profits decreases land prices by the same percentage, 13.3 %, under both policy experiments 1 and 2, while a 10 % increase in fertilizer prices decreases land prices by only 2.9 % under experiment 1 and 2.6 % under experiment 2. This illustrates that general macroeconomic factors may have effects on agricultural land prices that are far more important than minor fine-tuning in agri-environmental policies.

5. Concluding comments and policy implications

We developed a Ricardian model with land quality heterogeneity for analysing the effects of agri-environmental policies, as well as general tax and monetary policies, on agricultural land allocation and prices. Our analysis was oriented to the EU. Accordingly, the agri-environmental policy instruments we retained aimed to fit some of the main
features of the CAP situation. We thus considered an area payment policy, undifferentiated with respect to land quality or land-quality dependent, a cross-compliance requirement here represented by a mandatory buffer strip of a predetermined size, and a buffer strip payment policy granted to farmers for buffer strip sizes in excess of the minimum buffer strip area. The theoretical framework was illustrated by an empirical application to the Finnish agriculture focused on wheat producers who allocate their land between wheat and fallow.

The analytical part of the paper allowed us to define the comparative statics at the intensive margin of production. More precisely, it explored the comparative statics of fertilizer use and buffer strip size on a land parcel of a given quality. As expected, higher crop prices decrease the size of the voluntary buffer strip while higher input costs increase it. Higher area payments decrease the size of the voluntary buffer strip while higher buffer strip payments increase it. In other words, both crop area payments and buffer strip payments are not decoupled on a land parcel of a given quality as they affect the size of the voluntary buffer strip. The comparative static of land allocation with respect to area payments, mandatory buffer strip sizes and voluntary buffer strip payments shows that these instruments are not decoupled at the extensive margin of production. In other words, they have an impact on agricultural land allocation choice. More specifically, a non differentiated area payment and a buffer strip payment increase land area allocated to crop production. Increasing the mandatory buffer strip size decreases the land area allocated to crop production. Finally, the comparative statics of land prices shows how market and policy parameters affect agricultural land prices. Higher output prices, crop area payments and voluntary buffer strip payments increase
land prices while higher input costs and mandatory buffer strip sizes decrease it. The empirical illustration shows that general tax and monetary policies can be far more important than minor fine tuning in agri-environmental policies.

The empirical application supports the theoretical framework. In addition, it illustrates how important it is to consider the effects of the whole policy package and not each measure independently. This is because the latter may induce changes in agricultural land allocation. More precisely, we illustrated that a policy of crop area payments and mandatory buffer strips may have contrasting impacts on wheat production simply because adding a mandatory buffer strip to an area payment policy may have effects at the extensive margin of production by modifying agricultural land allocation. We also illustrated how market and/or policy parameters affect agricultural land prices and how changes in these parameters are capitalised into land prices. In particular, we showed that both uniform and quality-dependent area payments are capitalised into land prices, but the effects differ for each parcel according to its quality. First simulations suggest that the higher the quality of the land parcel, the greater the capitalisation. This result must however be considered as preliminary. It needs to be confirmed by further study. In the same way, our analysis needs to be completed by analysing how the policy instruments we considered affect agri-environmental externalities (nutrient runoffs, biodiversity, landscape diversity, etc.). This could be done using the analytical framework proposed by Lankoski and Ollikainen (2003).
References


Table 1. Alternative agricultural income support and agri-environmental policies

<table>
<thead>
<tr>
<th>Policy</th>
<th>Characteristics</th>
</tr>
</thead>
</table>
| Policy 1 | Uniform crop area payment \(s\).  
CAP compensation payment (€ 269 per hectare), LFA support (€ 150 per hectare) and national support (€ 105 per hectare) for wheat. Each hectare is thus entitled to a total payment of € 524. |
| Policy 2 | Quality dependent crop area payment \(s(q)\).  
Average quality production unit receives area payments totalling € 524 per hectare, of which the lowest quality unit is entitled to € 472 per ha and highest quality unit € 582 per ha. |
| Policy 3 | Policy 1 plus environmental cross-compliance.  
A mandatory three-meter-wide buffer strip. |
| Policy 4 | Policy 2 plus environmental cross-compliance.  
A mandatory three-meter-wide buffer strip. |

Table 2. Effects of alternative policy scenarios on fertilizer use, buffer strip size, land allocation, wheat production, per-hectare and total profits, and budget costs.

<table>
<thead>
<tr>
<th>Policy</th>
<th>Fertilizer use kg</th>
<th>Buffer strip share</th>
<th>Land allocation wheat : fallow</th>
<th>Total wheat production kg</th>
<th>Per-hectare profit €/ha</th>
<th>Total profit €</th>
<th>Total budget cost €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy 1</td>
<td>137.9 (129.9 - 145.6)</td>
<td>-</td>
<td>16 : 4</td>
<td>62 563</td>
<td>367.5 (327.3 - 408.2)</td>
<td>7168</td>
<td>9812</td>
</tr>
<tr>
<td>Policy 2</td>
<td>139.5 (133.3 - 145.6)</td>
<td>-</td>
<td>13 : 7</td>
<td>51 840</td>
<td>398.8 (331.6 - 466.4)</td>
<td>7439</td>
<td>9614</td>
</tr>
<tr>
<td>Policy 3</td>
<td>135.3 (126.9 - 143.4)</td>
<td>0.015</td>
<td>17 : 3</td>
<td>65 044</td>
<td>364.7 (322.5 - 407.4)</td>
<td>7166</td>
<td>9979</td>
</tr>
<tr>
<td>Policy 4</td>
<td>137.4 (131.3 - 143.4)</td>
<td>0.015</td>
<td>13 : 7</td>
<td>51 063</td>
<td>398.5 (331.8 - 465.6)</td>
<td>7435</td>
<td>9614</td>
</tr>
</tbody>
</table>
Table 3. Baseline land prices and the impact of a 10% increase in the market and policy instruments on land prices (€/ha).

<table>
<thead>
<tr>
<th>Baseline land prices, €/ha</th>
<th>Impact on land prices (€/ha) of a 10 % increase in</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crop price</td>
<td>Fertilizer price</td>
<td>Uniform area payment</td>
<td>Quality-dependent area payment</td>
</tr>
<tr>
<td>Policy 1</td>
<td>7350 (6545 - 8164)</td>
<td>8117 (6980 - 9270)</td>
<td>7148 (6464 - 7840)</td>
<td>8184 (7172 - 9212)</td>
</tr>
<tr>
<td>Policy 2</td>
<td>7977 (6632 - 9327)</td>
<td>8530 (6637 - 10434)</td>
<td>7777 (6556 - 9003)</td>
<td>8184 (6568 - 10375)</td>
</tr>
<tr>
<td>Policy 3</td>
<td>7294 (6450 - 8148)</td>
<td>8103 (6982 - 9238)</td>
<td>7148 (6474 - 7829)</td>
<td>8184 (7187 - 9196)</td>
</tr>
<tr>
<td>Policy 4</td>
<td>7971 (6635 - 9312)</td>
<td>8512 (6634 - 10401)</td>
<td>7775 (6563 - 8993)</td>
<td>- (6580 - 10360)</td>
</tr>
</tbody>
</table>

Table 4. Effects of voluntary buffer strip payments with policy 3 or 4 on fertilizer use, land allocation, production, per-hectare and total profits, and budget costs.

<table>
<thead>
<tr>
<th>Policy</th>
<th>Fertilizer use</th>
<th>Buffer strip share</th>
<th>Land allocation wheat : fallow</th>
<th>Total wheat production kg</th>
<th>Per-hectare profit €/ha</th>
<th>Total profit €</th>
<th>Budget cost €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy 3bis: policy 3 and buffer payment</td>
<td>133.1 (115.7 – 143.4)</td>
<td>0.032</td>
<td>17 : 3</td>
<td>64 019</td>
<td>365.0 (324.2 – 407.4)</td>
<td>7170</td>
<td>9976</td>
</tr>
<tr>
<td>Policy 4bis: policy 4 and buffer payment</td>
<td>135.2 (118.1 – 143.4)</td>
<td>0.027</td>
<td>14 : 6</td>
<td>53 984</td>
<td>393.2 (322.6 – 465.6)</td>
<td>7437</td>
<td>9763</td>
</tr>
</tbody>
</table>

Note: Buffer strip shares refer to shares in total wheat area, including parcels for which only mandatory buffer strips are implemented.
Table 5. Land prices under voluntary buffer strip payments

<table>
<thead>
<tr>
<th>Policy 3bis</th>
<th>Baseline land prices, €/ha</th>
<th>Impact on land prices (€/ha) of a 10 % increase in</th>
<th>Crop price</th>
<th>Fertilizer price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7299 (6485 - 8148)</td>
<td></td>
<td>8103 (6983 - 9238)</td>
<td>7154 (6507 - 7829)</td>
</tr>
<tr>
<td>Policy 4bis</td>
<td>7864 (6452 - 9312)</td>
<td></td>
<td>8514 (6652 - 10401)</td>
<td>7765 (6576 - 8979)</td>
</tr>
</tbody>
</table>

Table 6. Effects of general tax and monetary policy on after-tax land prices under wheat cultivation and fallowed

<table>
<thead>
<tr>
<th>Baseline land prices, €/ha</th>
<th>After-tax land prices (€/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t = 25% r = 0.05</td>
</tr>
<tr>
<td>Policy 1 (wheat)</td>
<td>7350 (6545 - 8164)</td>
</tr>
<tr>
<td>Policy 2 (wheat)</td>
<td>7977 (6632 - 9327)</td>
</tr>
<tr>
<td>Fallow</td>
<td>6440</td>
</tr>
</tbody>
</table>
### Appendix 1. Parameter values used in the empirical application

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price of wheat</td>
<td>$p$</td>
<td>€ 0.128/kg</td>
</tr>
<tr>
<td>Price of nitrogen fertilizer</td>
<td>$c$</td>
<td>€ 1.15/kg</td>
</tr>
<tr>
<td>Expenditure for other variable inputs than fertilizers</td>
<td></td>
<td>€ 186/ha</td>
</tr>
<tr>
<td>Labour costs</td>
<td>$\varphi$</td>
<td>€ 143/ha</td>
</tr>
<tr>
<td>Machinery costs</td>
<td>$k$</td>
<td>€ 168/ha</td>
</tr>
<tr>
<td>Area payments</td>
<td>$s$</td>
<td></td>
</tr>
<tr>
<td>CAP compensatory payments</td>
<td></td>
<td>€ 269/ha</td>
</tr>
<tr>
<td>LFA support</td>
<td></td>
<td>€ 150/ha</td>
</tr>
<tr>
<td>National support</td>
<td></td>
<td>€ 105/ha</td>
</tr>
<tr>
<td>Buffer strip payments</td>
<td>$\lambda$</td>
<td>375</td>
</tr>
<tr>
<td></td>
<td>$\omega$</td>
<td>340</td>
</tr>
<tr>
<td>Mitscherlich nitrogen response function</td>
<td>$\alpha$</td>
<td>4182 - 5164</td>
</tr>
<tr>
<td></td>
<td>$\beta$</td>
<td>0.0104</td>
</tr>
<tr>
<td></td>
<td>$\gamma$</td>
<td>0.7623</td>
</tr>
</tbody>
</table>
Appendix 2. Cross compliance and the savings in input costs versus loss of output

Policy 3

- Value of output loss
- Savings in input costs
1 We would like to thank Erik Lichtenberg for valuable discussions and J. Anton, W. Legg and W. Thompson for comments and suggestions on an earlier draft of this paper.

2 It is an empirical question to define which cost items are dependent or independent on actually cultivated area. Here, we only wish to highlight that this difference has crucial economic implications for the choice of the buffer strip size.

3 The difference equals zero for the minimum quality of land in crop production.

4 We did not include this tax in our analysis of agricultural production decision because it is neutral in terms of economic decisions.

5 Note that any policy or economic development reducing the size of cultivation costs, either $I$ or $F$, increases profits and thereby crop land prices.

6 “Operational profits” refer to the net profits over and above variable and parcel size dependent costs in (2) and (2'), i.e., $p f (l; q) - c l - I$.

7 In Appendix 2, we illustrate that the savings in input costs dominate the value of yield loss due to cross compliance for parcels 1 to 11.
Discussion Papers: