Evaluation of Agro-Environmental Policy through a Calibrated Simulation Farm Model

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Abstract: This paper evaluates the production and income effects from the adoption of one popular agro-environmental measure, which concerns buffer strips along field edges, on a representative sample of crop farms in Belgium taken from the Farm Accountancy Data Network database. We represent the economic behaviour of each crop farm with a profit-maximisation programming model that embeds an estimated *ex-ante* flexible cost function. We calibrate the simulation model using the Positive Mathematical Programming approach. Accounting for farm and regional heterogeneity, simulation results show how crop farms may respond differently to incentives for the agro-environmental measure. Results demonstrate that economic incentives can be an effective mechanism for encouraging uptake of agro-environmental measures and that impacts of agro-environmental measures can vary by farm and region, depending on agronomic conditions and the environmental potential for agro-environmental measure activity.

1. Introduction

Recent reforms in agricultural policy and changes to environmental regulations have altered the economic and regulatory landscape of the European agricultural sector. Introduced as accompanying measures to the 1992 Mac Sharry Reform of the Common Agricultural Policy (CAP), the agricultural environmental measures became part of the Rural Development Regulation (RDR) with the 2000 CAP reform. They accounted for 27.5 per cent of the total planned European Union (EU) contribution to rural development expenditures for the period 2000 to 2006 (Agrar CEAS Consulting, 2005). In 2005, the rural development policy was restructured into three thematic axes for the period 2007 to 2013: improving the competitiveness of the agricultural and forestry sector, improving the environment and the countryside, and improving the quality of life in rural areas and encouraging diversification of the rural economy. The agro-environmental measures became part of the second axis. Under these agro-environmental programmes, farmers receive compensation payments for the adoption of environmentally friendly production technologies. Agro-environmental payments are calculated on an acreage base and are meant to cover the income foregone plus additional costs for compliance. Participation in agro-environmental programmes is voluntary, restricted to farm enterprises and usually bound to renewable five year contracts.

The ADAGE model provides policy-makers with a tool for determining how farm cropping patterns and revenues are likely to respond to changes in output and input prices, quotas, yields, and environmental regulations in the Belgian Region of Wallonia. The ADAGE model is inter-disciplinary in nature, as it uses agronomic, environmental, and economic data to explore the holistic effects of economic and regulatory change on the farm. The core of the ADAGE model is an economic farm-level programming model that uses the Farm Accountancy Data Network (FADN) database to represent the farm decision-making process. The farm decision-making process is based on profit maximisation subject to the farm agronomic, environmental and institutional constraints as well as farm and regional resource constraints. The profit function embeds a flexible cost function that is econometrically estimated beforehand thanks to the farm database. The farm model is supplemented with location-specific information on soil type, erosion risk, and the geographic features specific to each farm which indicate the suitability of each farm to various agro-environmental measures and cross-compliance conditions.

The farm model is calibrated to a reference year using the same approach as in positive mathematical programming (PMP) (Howitt, 1995; Henry de Frahan *et al.*, 2007). In simulations, the results from each individual farm decision-making process can be aggregated using different criteria such as the farm location, type or size. Farms are assigned frequency weights in the aggregation so that the simulation results can be extrapolated to the entire Region of Wallonia. To demonstrate the capability of the ADAGE model, we present results from scenario simulations of farm response to changes in one specific agro-environmental measure that is second in popularity in terms of number of contracts in the Region of Wallonia. This agro-environmental measure concerns buffer strips along field edges to reduce water pollution from intensive farming and improve the ecological network.

The next section briefly introduces additional features of the ADAGE model. The third section presents the economic farm-level programming model of the ADAGE model. The fourth section provides the simulation scenarios and discusses their results. The last section concludes.

2. Modelling Setting

Several studies (Barreiro-Hurlé *et al.*, 2008; Bertoni *et al.*, 2008; Crabtree *et al.*, 1998; Defrancesco *et al.*, 2006; Delvaux *et al.*, 1999; Dupraz *et al.*, 2002; Dupraz *et al.*, 2000; Kazenwadel *et al.*, 1998; Vanslembrouck *et al.*, 2002; Wynn *et al.*, 2001) have analysed factors of adopting agro-environmental measures but few have actually modelled them at the farm level. Among these few studies, Judez *et al.* (2008) determine the minimum premium that is required to convert crops from being irrigated to their non-irrigated variant. Their PMP calibration technique does not, however, overcome the shortcomings of PMP as explained in Henry de Frahan *et al.* (2007). Helming and Schrijver (2008) analyse the economic and environmental effects of specific regional agro-environmental measures and direct payment redistribution on the Dutch agricultural sector in the perspective of a new CAP beyond 2014. They use a chain of models from the dairy farm level to the regional sector in the Netherlands to the European sector level to capture interactions among farms and markets. Their dairy farm-level model (FIONA) consists of several bio-economic models that represent certain types of dairy farm. The dairy herd size per farm and hectare and milk production per cow are, however, not endogenously determined within each representative farm model but are, instead, exogenously given via the Dutch regional agricultural sector-level model (DRAM) in combination with the European regional agricultural sector-level model (CAPRI).

In contrast to these two available applications, our modelling framework relies on a sample of farms that interact with each other via a common regional farmland constraint. Such interaction allows for exchanges of farmland among farms located in the same region and, hence, for endogenously-determined structural changes. The PMP concept is still used to calibrate these farm models but its use is limited to the correction of the estimated farm-specific flexible cost function.

The ADAGE model relies upon three information sources. The principle database used for the analysis is the Farm Accountancy Data Network (FADN), a farm survey conducted by every EU member state. The FADN contains detailed information on land allocation among different crops and livestock herd sizes and types, output levels and revenues, and input expenditures, as well as farmer socio-economic information. All information contained within the FADN is farm-specific; spatially explicit field-level information is not collected. For information at a finer resolution, we rely on two additional databases. The first, SIGEC (*Système Intégré de Gestion et de Contrôle*), contains field-level information on crops grown. It contains information on all farms in the region, as it is based on farmers' claims for subsidies from the European Commission. The second, METAGRE, contains information on the five-year agro-environmental contracts that bind farmers with the Region of Wallonia.

Although the ADAGE model utilised the FADN sample for the Region of Wallonia, the results presented here pertain only to the sub-sample of farms in the FADN that receive at least 60 per cent of their total revenues from cropping activities. This sub-sample is an unbalanced panel of 73 Walloon crop farms, observed during an 11-year period (1996-2006), located in the three agricultural regions of Wallonia most conducive to arable crop farming: Condroz, Sandy-Silty, and Silty.[1] The five cropping activities included in the model are chicory, potatoes, sugar beets, winter wheat, and an aggregate category of other cereals containing spring barley, spring oats, spelt, and winter barley. Seven inputs are included in the model: fertilizer, pesticides, seeds, contract services, cropland, variable inputs (electricity and gasoline), and capital inputs (building and machinery).

3. The Farm Model

Within the ADAGE model, profit-maximising farmers decide which economic activities to undertake in response to changes in the economic and regulatory landscape. At the heart of this profit maximisation model is a farm-specific cost function. The cost function is econometrically estimated using the 11 years of FADN survey data described above to determine how total farm costs and input demands vary in response to changes in output levels and input prices. In estimating a cost function using survey data, we must choose a functional form and determine whether the estimated cost function conforms to standard theoretical assumptions regarding cost functions. Our estimation method is based on Wieck and Heckelei (2007), and Henry de Frahan *et al.* (2011). We choose the Symmetric Generalized McFadden (SGM) from among the possible flexible functional forms because global curvature properties can be imposed on it without destroying the second-order flexibility (Diewert and Wales, 1987).

The principal benefit associated with embedding an econometrically estimated cost function within the profit-maximisation simulation model is the greater precision in cost function parameters that can be achieved through the use of multiple observations on the same farm. The most common application of the PMP method is to a single representative farm or region, because repeated observations on multiple data points are often not available. Because the FADN provides us with multiple observations over time

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[1] The two other agricultural regions of Wallonia are located in the southern, more mountainous part of Wallonia. Each contains between one to three FADN observations of arable crop farms, depending on the year. As our simulations include regional land markets, we excluded these farms from the analysis.

on many farms, we are able to separate out the effects of time-specific and region-specific effects and consequently isolate the effects of input prices and output levels on overall costs at the farm level. The model consequently allows for estimation of farm-specific cost functions, which can be used to simulate individual farm response to changes in agro-environmental policy. The details of our cost function estimation as well as the resulting parameter estimates generated for use in the policy simulations below are presented and described in Hansen *et al.* (2009).

Our method departs from previous research relying on the SGM cost function in one important respect. Diewert and Wales (1987) applied their use of the SGM cost function to U.S. manufacturing data of Berndt and Kahel. Wieck and Heckelei (2007) and Henry de Frahan *et al.* (2011) apply the SGM cost function to Belgian dairy farms. Production uncertainty is less central to these applications than it is to a model of north-western European crop production. In our application, farmers make input and land allocation decisions before they know what production levels, specifically yields, will be. To estimate a cost function using observed yields would be to assume that farmers predict perfectly what their yields will be at the time they decide how much land to allocate to each crop and how many other inputs to apply.

To avoid this pitfall, we estimate econometrically farmers' expected yields and use these in the cost function estimation rather than observed yields. We adopt the concept of an *ex-ante* cost function first suggested by Pope and Just (1996) and Moschini (2001). Hansen *et al.* (2009) contains the details of the method for calculating expected yields, as well as a comparison of the *ex-ante* cost function estimation using estimated yields and a conventionally estimated cost function using observed yields.

The first step of simulation is calibration. We calibrate on output levels observed in the reference year t (Howitt 1995; Henry de Frahan *et al.*, 2007). We denote the five cropping activities, chicory, other cereals, potatoes, sugar beets, and winter wheat, as the set C. Farms choose a set of expected output levels denoted by the function $\hat{Q}: C \to \Re_{\geq 0}$, assigning a non-negative quantity to each cropping activity in C, so as to maximise farm gross margin. We indicate the expected output level assigned by $\hat{Q}$ to a cropping activity m on farm f at time s by $\hat{Q}_{mfs}$ in the following basic objective function assuming that the farms in the sample are risk neutral:

$$\underset{\hat{Q}:C\to\Re_{\geq 0}}{Max}\left[\sum_{m\in C} P_{mfs}\hat{Q}_{mfs} + S_{fs} - \hat{C}_{fs}\left(\hat{q}_{fs}, w_{rt}, t\right) - \varepsilon_{ft}\right] \qquad (1)$$

The parameter P_{mfs} represents the output price, S_{fs} aggregate farm subsidies, and $\hat{C}_{fs}\left(\hat{q}_{fs}, w_{rt}, t\right)$ the *ex-ante* cost function which depends upon a vector of expected output levels $\hat{q}_{fs}$, a vector of input prices w_{rt}, and time t. The variable ε_{ft} is the error term from the cost function estimation procedure. Note that because expected output levels and prices may change in simulation, the time subscript for these variables is denoted by s rather than t.

This objective function is subject to the following constraints:

$$\hat{Q}_{mfs} \leq \hat{Y}_{mft} L_{mfs} \qquad \text{for } m \in C \qquad (2)$$

$$\hat{Q}_{SUGQ,fs} \leq Q_{SUGQ,ft} \qquad \text{for SUGQ = in-quota sugar beets} \qquad (3)$$

$$\hat{Q}_{SUGO,fs} \Big/ \hat{Q}_{SUGQ,fs} = \hat{Q}_{SUGO,ft} \Big/ \hat{Q}_{SUGQ,ft} \qquad \text{for SUGO = out-of-quota sugar beets} \quad (4)$$

$$\hat{Q}_{mfs} \leq \hat{Q}_{mft} + \varepsilon_{mft} \quad [\lambda_{mft}] \qquad \text{for } m \in C \quad (5)$$

Equation (2) gives the expected output level for each crop *m* as a function of expected yield $\hat{Y}_{mft}$, estimated by the method described above, and land planted in crop *m*, L_{mfs}, expressed in tens of hectares on each farm *f*. Equation (3) limits the expected quantity of sugar beets under quotas A and B to the quantity of sugar beet observed under quota in the reference year *t*. Equation (4) fixes the simulated relationship between in-quota and out-of-quota sugar beet production observed in the reference year *t*. This constraint is a simplification of the complementary relationship observed between the two types of sugar beet production (see Buysse *et al.* (2007) for more details).

The last constraint in this system of equations is the production calibration constraint, which is used to calibrate the farm model. The maximisation problem comprising equations (1) to (5) produces shadow values λ_{mft} on the perturbation terms ε_{mft} which indicate the increase in the objective function that occurs from relaxing the calibration constraint by one unit. The logic is as follows: it must be the case that a profit-maximizing farm incurs additional costs equal to λ_{mft} in producing activity *m* in the reference year *t*. If costs were lower, the farm would produce more of activity *m*; if costs were higher, it would produce less. These shadow values can be interpreted, as they are by Howitt (1995), as representing factors not explicitly included in the model itself at reference year *t*, such as risk, measurement error, and price expectations. In contrast to other PMP applications, the calibration model (1) to (5) does not include a farm-level cropland constraint. Thus the shadow values λ_{mft} also reflect other factors that constrain farms to the specific size observed at reference year *t*. The calibration model does not include a farm-level cropland constraint because we prefer to use a long-run cost function allowing for trade of cropland in simulations.

The shadow values generated by the calibration model (1) to (5) can then be used to calibrate the simulation model. Equation (5) forces the model to replicate output levels observed in the reference year *t*. In simulation, we replace equation (5) with a penalty quadratic function that allows farms to deviate from output levels observed in the reference year, but at a cost. The objective function for simulation is thus:

$$\underset{\hat{Q}:C \to \Re_{\geq 0}}{Max} \sum_{f \in R} \left[\sum_{m \in C} P_{mfs} \hat{Q}_{mfs} + S_{fs} - \hat{C}_{fs}\left(\hat{q}_{fs}, w_{rt}, t\right) - \varepsilon_{ft} - \sum_{m \in C} \frac{\lambda_{mft} \hat{Q}^2_{mfs}}{2\hat{Q}_{mft}} \right] \omega_{fs} \qquad (6)$$

for each agricultural region *R* where the last parameter ω_{fs} denotes the frequency weight of the farm *f* in the total population to allow for extrapolation of farm-specific simulation results to the regional level.

Note that the optimization in equation (6) occurs at the regional level, so that farms within the same agricultural region *R* may trade cropland among themselves. We add a regional cropland constraint to ensure that the area of cropland used within a region is not larger in simulation, *s*, than is observed in the reference year, *t*:

$$\sum_{f \in R} \sum_{m \in C} L_{mfs} \leq \sum_{f \in R} \sum_{m \in C} L_{mft} \qquad \text{for } R = \text{Condroz, Sandy-Silty, and Silty regions} \quad (7)$$

In sum, the calibrated simulation model consists of the objective function (6) modified to incorporate calibration terms as well as constraints on the relationship between production and yields, sugar beet production, and the regional land market (equations 2, 3, 4 and 7). We are now ready to simulate farm responses to changes in agro-environmental policy.

4. Simulations of an Agri-environmental Measure

The agro-environmental measure that we model as an illustration concerns vegetated buffers strips along field edges. This measure provides a premium of 900 €/hectare to farmers who plant buffer strips of 6 to 12 meters in width along field edges.[2] Our model answers two questions. First, how would farmers adjust their cropping patterns in response to a change in the size of the buffer strip premium? Second, how would farmers adjust their cropping patterns if buffer strips are required? Because the latest data on observed buffer strip activity are for 2004, we use 2004 as the reference year for these simulations. According to the 2004 regulation, the minimum cropland area that can benefit from the premium is 800 m². Farms cannot convert more than 8 per cent of their cultivated cropland or more than 50 per cent of any one field to buffer strips. The maximum authorised area in buffer strips is determined by the minimum of these two requirements (Gouvernement wallon 2004, pages 395-400).

For the first question, we decrease and increase the 2004 premium by 10 per cent and 25 per cent to observe farm responses to these new economic incentives. First, farms within the model must be permitted to implement buffer strips. The set of cropping activities now available to farms is denoted by *C'*, the original cropping activity set *C* augmented by the buffer strip activity (*m*=BU). Accordingly, we replace equation (2) in the model with equation (10):

$$\hat{Q}_{mfs} \leq \hat{Y}_{mft} L_{mfs} \qquad \text{for } m \in C' \qquad (10)$$

with the understanding that one hectare of buffer strip activity yields one unit of buffer strip activity, $\hat{Y}_{BUft} = 1$.

Revenues and costs from the buffer strip activity must also be added to the basic simulation model. Further, now that farms can choose how much buffer strip to undertake in response to premium changes, the buffer strip activity must be calibrated along with the original cropping activities. However, buffer strips were not included in our cost function estimation, as the FADN does not report the cost of implementing buffer strips. Like the conventional cropping activities, we can reasonably assume that at the margin, the premium for buffer strips is equal to the marginal cost of implementing buffer strips. We consequently extend the original calibration constraint (5) to include the buffer strip activity with equation (11):

$$\hat{Q}_{mfs} \leq \hat{Q}_{mft} + \varepsilon_{mft} \quad [\lambda_{mft}] \quad \text{for } m \in C' \qquad (11)$$

We only perform the buffer strip simulations on a subset of farms in the 2004 FADN data because calibration on an activity not undertaken in the reference year is impossible. For each region *R*, let $F_{BU}(R)$ equal the set of farms in region *R* that undertake buffer strips. The objective function of equation (6) is consequently modified as follows:

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[2] The premium of a similar but more targeted measure that has a greater ecological value regarding, for instance, habitat protection is increased to 1250 €/hectare to compensate for the additional costs.

$$\underset{\hat{Q}:C'\to\Re_{\geq 0}}{Max} \sum_{f\in F_{BU}(R)} \left(\sum_{m\in C'} P_{mfs}\hat{Q}_{mfs} + S_{fs} - \hat{C}_{fs}\left(\hat{q}_{fs}, w_{rt}, t\right) - \varepsilon_{ft} - \sum_{m\in C'} \frac{\lambda_{mft}\hat{Q}^2_{mfs}}{2\hat{Q}_{mft}} \right)\omega_{ft} \qquad (12)$$

for each agricultural region *R*. The premium for buffer strips P_{BUfs} changes from 75 per cent to 90 per cent, 100 per cent, 110 per cent, and 125 per cent of the 2004 level, successively, for each simulation scenario.

The land constraint of equation (7) is altered to incorporate the buffer strip activity. Total cropland is now the sum of land allocated to the original five activities as well as to buffer strips:

$$\sum_{f\in F_B(R)} \sum_{m\in C'} L_{mfs} \leq \sum_{f\in R} \sum_{m\in C'} L_{mft} \qquad \text{for } R = \text{Condroz, Sandy-Silty, and Silty regions} \quad (13)$$

We include for completeness a requirement that the farm not undertake more buffer strips than is permitted under the 2004 regulations:

$$L_{BUfs} \leq LMAX_{BUft} \qquad (14)$$

where the parameter $LMAX_{BUft}$ is the maximum authorised area that can be planted in buffer strips in 2004.[3] This last constraint is never binding, however, because the net revenue associated with undertaking buffer strips is smaller than the net revenue associated with other activities the farm could undertake on its cropland. The buffer strip premium simulation model is then composed of equations (3), (4), (10), and (12) to (14).

For the second question, we add a mandatory requirement to undertake at least a minimum of buffer strips. This regulation is interesting to simulate because buffer strips along waterways are likely soon to become a cross-compliance requirement. The minimum cropland area that a farmer must set aside for buffer strips is dictated within the model by $LMAX_{BUft} \cdot \%_{BUs}$. The parameter $\%_{BUs}$ is the minimum percentage of $LMAX_{BUft}$, that is required to be planted in buffer strips. The parameter $\%_{BUs}$ takes the values of 0, 25, 50, 75 and 100 per cent successively for each scenario. The following equation consequently governs the mandatory buffer strip requirement:

$$L_{BUfs} \geq LMAX_{BUft} \cdot \%_{BUs} \qquad (15)$$

The objective function and regional cropland constraint are identical to those in the buffer strip premium simulations above. Thus, the simulation model for mandatory buffer strips is composed of equations (3), (4), (10), and (12) to (15).

The first two lines of Table 1 indicate the number of crop farms in the FADN sample as well as the cropland area planted on those farms by agricultural region in 2004. The next two lines give the number of farms that undertake buffer strips as well as the cropland area planted on those farms by agricultural region. The fifth and sixth lines give the associated buffer strip area, in both absolute and relative terms. The seventh and eighth lines indicate the maximum area of cropland eligible for buffer strips for these farms according to the regulations in effect in 2004 by agricultural region, in both absolute and relative terms. The 15 farms that undertake buffer strips in 2004 have an average of 1.75 hectares in buffer strips, which corresponds to 24 per cent of the maximum cropland eligible for the measure. Table 1 also indicates cropland allocation to other crops for these 15 farms.

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[3] The calculation of $LMAX_{BUft}$ is made in the software programme ArcGIS using information on field size and shape from the SIGEC database. Fields that are too narrow to be planted in buffer strips tend to reduce the maximum cropland area that can be planted in buffer strips on a farm from 8 per cent.

Only 15 farms in the reference year plant any buffer strips. For the remaining farms, it seems that the buffer strip net revenues are smaller than the shadow value of the least profitable activity. Presumably, at least some of the remaining 31 farms in the sample would implement buffer strips if the premium were large enough to offset their cost of implementing buffer strips or the transaction costs associated with adopting buffer strips for the first time. Buffer strips would become profitable relative to the least profitable activity, and the farm would begin to implement them. However, without any information from non-adopting farms regarding their reasons for not implementing buffer strips, we do not know how large the premium would have to be to entice them to adopt. Thus we restrict our simulations to the 15 farms in the sample for which we are able to observe farm preferences for buffer strip activity.

We first simulate the response of the 15 farms that undertake buffer strips in 2004 to changes in the premium from 75 to 125 per cent of the 2004 premium. A premium increase augments the cropland planted in buffer strips to the detriment especially of land planted in winter wheat and to a lesser extent potatoes, other cereals, and chicory (Figure 1). Conversely, a premium decrease causes farms to substitute away from planting buffer strips to winter wheat and to a lesser extent potatoes, other cereals, and chicory. However, the response to variation in the buffer strip premium is of a relatively small magnitude. Even in the more severe simulations, the impact on the gross margin of these 15 farms is weak (top section of Table 2).

The pattern of crop displacement resulting from a minimum buffer strip requirement is somewhat different than that observed resulting from variations in the buffer strip premium. The 15 crop farms of the FADN sample tend to decrease cropland planted in winter wheat, chicory, other cereals, and potatoes, as the minimum buffer strip requirement is increased (Figure 2). For all but two crop farms in the FADN sample, winter wheat and other cereals are the two activities with the lowest gross margin. This explains why winter wheat is primarily removed from production when buffer strips are imposed. The interdependence of winter wheat with the other cropping activities in the cost function causes more profitable crops, primarily potatoes, also to be removed from production.

Because the ADAGE model is farm-specific, we are able to observe how individual farms change their cropping patterns in response to changes in the buffer strip regulation. There is substantial variation in how farms within a single region respond, yet the three regional averages are not significantly different than one another. This suggests far greater variability between farms than between regions in response to buffer strip requirement.

Of the three regions modelled, the Condroz region is the least affected by the buffer strip requirement. On average, farms experience a 26 per cent decrease in farm gross margin as a result of the most severe simulation, when the buffer strip requirement is set at its maximum (bottom section of Table 2). This is a rather severe decrease, reflecting both the fact that 8 per cent of land is required to be planted in buffer strip in that simulation and the fact that we use a quadratic cost term to calibrate the buffer strip activity. If costs are higher or lower than we have assumed, farms may respond differently than our model indicates.

5. Conclusions

The ADAGE model has demonstrated the feasibility of using calibrated simulation models in evaluating the agronomic and economic effects of changes to agro-environmental regulations. We represent the economic behaviour of each crop farm with a profit-maximisation programming model, and demonstrate how farms are likely to respond to changes in one important agro-environmental regulation, which concerns buffer strips along field edges, all the while accounting for farm and regional heterogeneity. Our results suggest that economic incentives can be an effective mechanism for encouraging uptake of an agro-environmental measure and that impacts of an agro-environmental measure can vary substantially by farm and region, depending on agronomic conditions and the environmental potential for agro-environmental measure activity. For instance, raising the premium for buffer strips by 25 per cent would stimulate the adoption of buffer strips in the same proportion while being almost neutral to land allocation and farm gross margins in the three agricultural regions under study. However, imposing buffer strips on more than half of cropland eligible for buffer strips starts to modify land allocation and reduce farm gross margins by more than 5 per cent.

The farm is the most meaningful unit of analysis for an economic optimisation model of agricultural behaviour, since the farmer takes into account the quality and quantity of his land and other inputs when making cropping decisions. What a farm-level model is not able to do quite as gracefully is to incorporate field-specific information on soil quality. To the extent possible, however, we have incorporated spatially explicit information related to field suitability for agro-environmental measures into the ADAGE model.

The use of calibrated simulation models which draw data inputs from multiple disciplines clearly has the potential to assist policymakers in crafting policy that achieves their goals. Such models may provide them with a more sophisticated understanding of the likely effects of their policies. However, some work for the future remains. First, a profit-maximization optimization model only takes into account economic costs and benefits. The possibility exists that farmers choose to undertake agro-environmental measures for non-economic reasons. To some extent, we can capture these effects through the PMP calibration. However, we do not model behaviour directly. If a behavioural shift were to occur, perhaps as a result of an education program on the environmental dangers of nitrate leaching, our model would not capture these effects. Second, we would have liked to have modelled the response of farms that did not undertake buffer strips in the reference period to changes in the buffer strip premium. If the buffer strip premium were to increase sufficiently, many if not all farms in our sample would have undoubtedly undertaken some buffer strips. However, absent information on farmers' reasons for not adopting buffer strips, it is impossible to estimate their reservation price. Non-economic motivations for undertaking agro-environmental measures and lack of revealed preference for buffer strips by some farms are two examples of areas where other methods, for example stated preference survey techniques, might supplement the current methodology to some advantage.

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Table 1. Land allocation for crop farms undertaking buffer strips in the 2004 FADN sample by agricultural region

		Agricultural Region			
	Unit	**Condroz**	**Sandy-Silty**	**Silty**	**Three-region total**
Crop farms in the sample	Number	10	5	31	46
Cropland	Ha	645.1	325.0	1644.8	2614.9
Crop farms in the sample with buffer strips	Number	6	2	7	15
Cropland	Ha	474.9	129.5	339.3	943.6
Buffer strips	Ha	14.2	2.5	9.5	26.2
	as % of cropland	2	1	1	1
Maximum buffer strips	Ha	53.4	11.7	42.3	107.4
	as % of cropland[a]	11	9	12	11
Chicory	Ha	0.0	15.7	22.4	38.1
	as % of cropland	0	12	7	4
Other cereals	Ha	95.3	3.9	55.9	155.1
	as % of cropland	20	3	16	16
Potatoes	Ha	66.3	7.0	9.4	82.7
	as % of cropland	14	5	3	9
Sugar beets	Ha	78.6	35.1	69.6	183.3
	as % of cropland	17	27	21	19
Winter wheat	Ha	234.6	67.8	182.0	484.4
	as % of cropland	49	52	54	51

Sources: METAGRE and FADN

(a): Regional proportions are larger than the 8% maximum due to minor discrepancies between the METAGRE and FADN databases.

Table 2. Changes in farm gross margins (%) in response to agro-environmental policy changes for buffer strips by agricultural region

Voluntary buffer strip measure for the crop farm sample with buffer strips in 2004

Buffer strip premium as a percentage of base year premium	Condroz	Sandy-Silty	Silty	Three-region total
75%	99.35	99.28	99.87	99.57
90%	99.70	99.68	99.92	99.79
100%	100.00	100.00	100.00	100.00
110%	100.36	100.36	100.12	100.25
125%	101.01	100.99	100.36	100.72

Mandatory buffer strip measure for the crop farm sample with buffer strips in 2004

Minimum percentage of maximum buffer strip undertaken	Condroz	Sandy-Silty	Silty	Three-region total
0%	100.00	100.00	100.00	100.00
25%	99.85	99.23	98.73	99.08
50%	96.23	94.85	93.65	94.45
75%	89.82	86.75	84.02	85.83
100%	80.80	74.95	70.66	73.77

Figure 1. Percentage changes in cropland allocation in response to changes in the buffer strip premium.

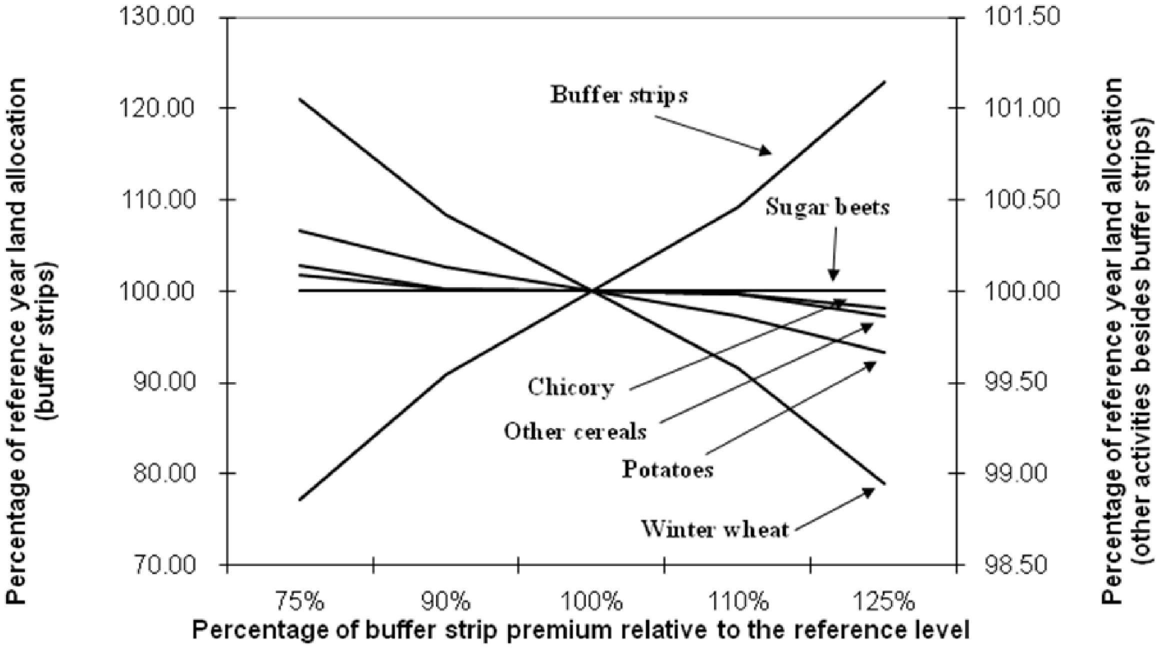

Figure 2. Percentage changes in cropland allocation in response to minimum mandatory buffer strips