# On The Empirics of Ecosystem Services Schemes:
# Technology, Risk and Compliance

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Abstract
The overall aim of this study is to empirically investigate the cost structure of a management agreement type agri-environmental instrument and to identify factors for cost variation over space and time. We control for the actual level of compliance by using compliance weighted average scheme cost ratios. Beside technological and economic performance measures, we also incorporate risk proxies. In addition, we consider unobserved heterogeneity or path dependency with respect to unknown administrative, spatial and farm specific factors. Hence, we try to disentangle random and fixed scheme cost effects by applying a bootstrapped mixed-effects regression approach using the empirical case of the Environmental Stewardship Scheme in the UK. Regional and sectoral variation in the scheme uptake and the cost of compliance for the participating farms lead to significant cost effects reflecting heterogeneity with respect to management skills and attitudes, production focus, location, technologies, economic performance and risk.

*Keywords* - Environmental Policy, Ecosystem Services, Risk, Mixed-Effects Panel Regression

*JEL* - Q18, Q57, Q58

## 1 - Introduction[1]

Policies to encourage the provision of agri-environmental goods have been introduced and developed since the 1980s as a consequence of rising concerns that agricultural support measures have led to a threatening level of land use intensity. Quantitative evaluations of alternative agri-environmental policy instruments need to include beside the actual payments to farmers also various types of transaction costs to increase the efficiency of policy choice and the sustainability of policy design (Falconer et al. 2001, McCann et al. 2005). Such transaction costs include the costs of instrument design, administration, monitoring and evaluation, as well as inspection and enforcement. To date, still only a few studies consider such costs in empirical terms despite a widespread recognition of their importance, especially with respect to the administrative cost component (Stavins 1993, Whitby and Saunders 1996). Organisational costs should be balanced with maintaining sufficient levels of conservation activity to fulfill the specific objectives of the environmental policy, hence the relation between costs and policy effects matters to policy makers (Falconer et al. 2001).

The policy relevant question is how agri-environmental expenditures relate to improving environmental quality and social welfare as compared to the ‘policy-off’ scenario. Consequently, transparency with respect to the factors that cause schemes to be more or less costly to run would enable policy-makers to identify possible adjustments to improve the efficiency of these schemes. Relative inefficiency of instruments can be caused by factors related to policy management characteristics but also by factors related to recipients’ characteristics. The latter comprises beside individual characteristics as e.g. risk considerations, also such characteristics related to production as well as prevailing environmental conditions as e.g. altitude and precipitation.

We use the case of the Environmental Stewardship Scheme (ESS) currently in operation in the UK. Here agricultural producers agree to modify their production activities to benefit the environment and are compensated for the costs they so incur. We aim to contribute to the literature in the following ways: There are still only a very few empirical studies available investigating the performance of environmental schemes using microdata at the farm level. We control for the actual level of compliance per region by using compliance weighted average scheme cost ratios. Beside technological and economic performance measures, we also consider proxies for risk at farm level. By this we go further than existing studies on ecosystem services schemes and aim to empirically investigate the theoretically well explored policy implications of adverse selection and moral hazard. In addition, we consider unobserved heterogeneity or path dependency with respect to unknown spatial and farm specific factors. Hence, we try to disentangle random and fixed scheme cost effects by applying a mixed-effects estimation approach.

By applying a three-stage estimation procedure we significantly contribute to the literature by improving on earlier empirical studies: In a first step we calculate (compliance weighted) scheme cost-effect ratios on the regional level with respect to the administratively relevant government office regions for different years. After statistically testing for the robustness of these ratios by bootstrapping tools we then apply adequate regression techniques to estimate the marginal impact of different factors on the scheme cost variation at regional level. Based on the estimation of a transformation frontier and the estimation of the moments of the farms' profit distributions we add additional explanatories reflecting the farms' production structure and performance as well as the farmers' risk attitudes. The estimated coefficients indicate how the cost-effectiveness of the policy measure is expected to vary at the margin with large and statistically significant parameters pointing towards important recipient subgroups and/or recipients' characteristics. We simultaneously model fixed and (unobservable) random scheme cost effects by avoiding inconsistencies implied by other estimators applied in earlier studies (see Falconer et al 2001).

The next section discusses the economics of a management-agreement-type instrument followed by section 3 introducing the different costs related to policy measures in general and agri-environmental instruments in particular. Section 4 describes the Environmental Stewardship Scheme operated in the UK as a prominent example for an agri-environmental voluntary-agreement-type instrument. The empirical methodology is outlined in section 5, followed by the exposition and discussion of the estimation results (section 6). Section 7 formulates policy implications and concludes.

## 2 - Voluntary-Agreement-Type Agri-Environmental Instruments

The use of economic instruments is especially promising when the appropriate response varies between regulated firms, and when information problems exist leading to an asymmetric distribution of knowledge about firm technology and input choices and hence production costs (see Weitzman 1974, Stavins 1996 and Hepburn 2006). In the area of agri-environmental policy economic instruments for conservation purposes (as e.g. market-based mechanisms such as eco-certification) are usually subsumed under the heading of payments for environmental services (PES). Following Wunder (2005) and Pagiola et al. (2007), payment schemes for environmental services generally have two common features: (1) they are voluntary agreements, and (2) participation involves a management contract (or agreement) between the conservation agent and the landowner. The latter agrees to manage an ecosystem according to agreed-upon rules (e.g. reducing fertiliser usage or stocking rates, or providing a public good by fencing to exclude stock from remnant bush) and receives a payment (in-kind or cash) conditional on compliance with the contract.[2] Such contractual relationships are subject to asymmetric information between landowners and conservation agents limiting the schemes' effectiveness and increasing the cost of implementation (see also Bolton and Dewatripont 2005).

### *Information Asymmetries*

Information asymmetries in the design of such contracts relate to hidden information and hidden action. Hidden information (leading to adverse selection) arises when the service contract is negotiated: Landowners hide information about their opportunity cost structure with respect to supplying the environmental service and, hence, are able to claim higher costs of provision and finally higher payments. Ferraro (2008) points out that landowners use their private information as a source of market power to extract informational rents from the conservation agent. These rents are payments above the required minimum payment to induce landowner participation in the conservation program. In the light of tax-funded environmental services involving deadweight losses and free riding, suboptimal funding levels are the result compared to the optimal case where the opportunity costs of supplying environmental services would be completely known by the conservation agent.[3] Hidden action (or moral hazard) arises after the contract has been negotiated leading to costly monitoring and enforcement in the case of non-compliance on the side of the conservation agent. The agent might not be able to perfectly monitor and/or enforce compliance or might choose not to monitor and/or enforce compliance. Hence, the landowner has an incentive to avoid the fulfillment of the contractual responsibilities and to seek rent through non-compliance (e.g. Ozanne and White 2008).[4]

*Compliance*

Economists usually model the compliance decision of a firm or farm as a choice under risk with monitoring being essentially a random process (see e.g. Heyes 1998). Let us suppose that there exists some regulation (e.g. the requirements by a conservation contract) requiring a farm or landowner to execute action *a* (e.g. to reduce the use of chemicals on a particular piece of land). If the cost to comply with that regulation for farm i is $c_i$, the probability of non-compliance being detected is $\eta$, and the penalty for non-compliance is $p$, then a profit-maximising and risk neutral farm will comply if and only if

$$c_i \leq \eta p \tag{1}$$

or

$$\eta p - c_i \geq 0 \tag{2}$$

Those farms that find

$$\eta p - c_i \geq t_i \tag{3}$$

where $t_i$ denotes a farm specific treshold, will comply and execute action *a*. The rest will take the risk of being caught and fined with $\eta p$. However, what matters in environmental and hence policy terms is the compliance rate across all farms taking part in the agri-environmental scheme j, say $\gamma_j$. Farms differ with respect to $c_i$ and $t_i$ reflecting differences in managerial skills, technology, location but also individual attitudes and experiences. If $c$ is distributed according to some cumulative distribution $F(c_i)$, then the compliance rate across all farms taking part in the scheme, $\gamma_j$, can be expressed as a function of the enforcement policy parameters

$$\gamma_j = F(\eta p) \tag{4}$$

By raising $\eta$ - the probability that non-compliance will be penalized - and/or raising $p$ - the size of the penalty - compliance becomes more attractive to the farm and so $\gamma_j$ increases. The magnitude of such an increase (i.e. the effectiveness of a raise in $\eta$ and/or p) will depend on the shape of $F$.[5] For any given scheme population compliance rate $\gamma_j$ the distribution of compliance effort between farms is efficient - as it is always those farms with the lowest compliance cost $c_i$ that do comply (Heyes 1998). Hence, the conservation agent maximizes compliance (i.e. minimizing environmental damage) by setting both $\eta$ and $p$ as high as possible. Full compliance is only ensured if $\eta p$ exceeds the upper bound of $c$. In most cases, however, this will not be possible because of budgetary, legislative and other constraints.

In a more realistic setting, the compliance decision faced by each farm is continuous in character, i.e. a farmer will typically have to choose a level of compliance, i.e. a level of action *a* (e.g. reducing the use of chemicals *ch* on a particular piece of land) which is inherently continuous variable. Farm *i* is subject to a regulatory standard which forbids it from using input $ch_i$ beyond some level *s*. Assume that the expected penalty for exceeding the level *s* is an increasing function $p(ch_i - s)$ of the size of the violation and compliance costs are increasing according to a function $c(ch_i)$. Then the farm *i* has to choose a level of input to minimize

$$c(ch_i) + p(ch_i - s) \tag{5}$$

The first-order condition provides the solution $ch_i$*

$$c'(ch_i^*) = -p'(ch_i^* - s) \tag{6}$$

The farm uses the detrimental input up to the point at which the marginal cost (i.e. foregone profit) of further decreasing input *ch* equals the marginal saving in terms of expected penalties. The size of the violation depends only on the marginal, not the average properties of the expected penalty function which is the essential message of the 'theory of marginal deterrence' (e.g. Shavell 1992).[6] As average and marginal penalties do not always move in the same direction, one enforcement regime may involve harsher penalties but have a 'flatter' penalty structure (see Segerson 1988, Stavins 1996).

Ozanne et al (2001) find that the moral hazard problem can be eliminated if monitoring costs are negligible or fixed, or farmers are highly risk averse. Optimal monitoring effort declines with increasing farmer risk aversion. Based on Moxey et al (1999), White (2002) suggests that where the regulator faces both hidden costs and hidden actions, an input charge policy can significantly reduce the costs of effective mechanism design. Fraser (2002) shows that risk averse farmers who face uncertainty in their production income are more likely to comply with agri-environmental schemes as a means of risk management. The author concludes that risk management by both principals and agents has the potential to diminish the moral hazard problem. By introducing uncertainty about farmer characteristics into the moral hazard problem Hart and Latacz-Lohmann (2005) find, that if farmers are overwhelmingly honest then the regulator reduces monitoring and accepts that some dishonest farmers will escape undetected. Paradoxically, their model also suggests that the total number of cheating farmers increases as the number of honest farmers increases. Ozanne and White (2008) analyse the design of agri-environmental schemes for risk-averse producers whose input usage is only observable by costly monitoring. They conclude that if the scheme is designed in such a way that producers always comply with an input quota, risk aversion is not relevant in determining the level of input use. Fraser (2009) examines the issue of incentive compatibility within environmental stewardship schemes, where incentive payments are based on foregone agricultural income. He conlcudes that given land heterogeneity, environmental goods and services are likely to be systematically over- or underprovided in response to a flat rate payment for income foregone. Finally, the analysis by Zabel and Roe (2009) investigate the question how to optimally adjust incentives in a performance payment scheme in the presence of (i) risk, i.e. external environmental noise in the production process and (ii) distortion in the performance indicators used. They suggest, that when (most commonly) only one indicator is used, the incentive payment should decrease as external noise - as the farmer's coefficient of absolute risk aversion - increases. Relative performance evaluation could be a viable approach to back-out such risk, whereas issuing threshold payments instead of continuous payments is a strategy to cope with non-normally distributed noise.[7]

Heyes (1998) and others note a particular empirical regularity with respect to the compliance of firms which is referred to as the 'Harrington paradox': Firms appear to over-comply - to comply more fully and/or more frequently than would be suggested by consideration of the private costs and benefits of so doing. Alternative rationales for such an irrational compliance behaviour can be found in the literature. (i) Voluntary compliance: So far we have assumed that farms are cynical profit-maximizers. It is sometimes contended that there is in fact such a thing as a 'green corporation' which has a social conscience and attaches weight to its environmental performance *per se*. The main problem with such a theory is evolutionary - a farm that forgoes profit to pursue other objectives (green or otherwise) is likely to find itself displaced in the market by one that does not (Arora and Cason 1996). (ii) Misjudgement: It may be that potential non-compliers overestimate the probability that wrong-doing will be detected or the penalties that such detection would trigger. (iii) Penalty leverage: Various contributions emphasize the repeated nature of the interaction between firm and agency. Such repetition can lead to the agency conditioning its attitude towards a particular firm's past 'compliance record' resulting in apparent over-compliance at any given moment (see e.g. Harford 1991). (iv) Regulatory dealing: Conservation agencies or regulators in general interact with a given farm in more than one context (the farmer may operate several holdings, operate at different locations, or be subject to different environmental regulations). Hence, there is scope for the agency to exploit 'issue-linkage' and farms may *appear* to over-comply in a given setting, but in reality are so doing in exchange for the agency 'turning a blind eye' somewhere else (at another holding, or in its enforcement of some other regulation). These explanations are neither exhaustive nor mutually exclusive. The relative importance of different effects will depend upon a range of factors and contextual influences.

*Social Interaction*

As outlined before, landowners or farms differ with respect to the cost of compliance $c$ and the compliance cost treshold $t$ reflecting differences in managerial skills (**m**), technology (**tech**), location (**l**) but also individual attitudes and experiences (**att**). Hence, the individual farm's cost of compliance with the requirements of scheme $j$ can be described as a function of these characteristics

$$c = F(\mathbf{m}, \mathbf{tech}, \mathbf{l}, \mathbf{att}, \varepsilon) \qquad (7)$$

where $\varepsilon$ denotes stochastic influences on the farm's cost of compliance structure with respect to scheme j. The vector of technological characteristics (i.e. input/output levels and interactions) includes also the choices with respect to the detrimental input *ch*. Managerial skills can be further described as a function of different individual and socioeconomic characteristics as e.g. age and education of the farmer, whereas the farmer's attitudes and experiences with regulatory instruments and in particular agri-environmental scheme compliance can be described as a function of a bunch of observable and non-observable factors. Sunding and Zilberman (2001) point out that a complete analytical framework for investigating scheme adoption and compliance decisions should include information gathering, learning by doing and resources' accumulation.

Rosenberg (1982) distinguishes between three different forms of learning: 'learning by doing', 'learning by using', and 'traditional learning'. Learning by doing relates to the supply of the technology or program (here the conservation scheme), hence does not provide an explanation for why a farm would show a poor or high compliance. Learning by using describes the effect of the users of a given technology or program (i.e. the demand side) which leads to decreasing $c_i$ over time as farmers learn how to better comply with the regularities of the new scheme. Finally, traditional learning as the most commonly discussed form of learning which involves potential scheme participants gathering information about the conduct of a new scheme (i.e. its expected costs and variance). Landowners are uncertain about the value of the new scheme and are thus hesitant to agree to the requirements without having sufficient information on its conduct and performance. Such information may be obtained by observing and interacting with others participating and complying with the scheme (i.e. peer-group spillover effects, informational cascades), by talking to the conservation agency (i.e. scheme suppliers), or by experimenting with the new scheme themselves.[8] Baerenklau (2005) points out, that traditional learning in the sense of 'learning from others' is more complicated as it may become rational for a forward-looking agent to postpone (non-)compliance (at least partially) until better information becomes available regarding the expected benefit of (non-)compliance. Such farmers would tend to 'wait and see' what happens to their neighbouring non-compliers (i.e. free-riding on others' scheme experiences) before they assume the expected private costs of non-complying with the scheme themselves (i.e. an information or network externality).

Social scientists have examined such effects in several theoretical contributions (e.g. Coleman et al. 1966, Schelling 1971, for a more recent overview see also Brock and Durlauf 2001). However, with respect to empirical modelling confounding identification problems have to be considered (Manski 1993): i) endogenous (peer-group or neighborhood) effects refer to the phenomenon that the propensity of a farmer to behave varies with the behaviour of his peer-group; ii) exogenous (contextual: time and space related, i.e. fixed) effects describe the covariance between the propensity of a farmer to behave and exogenous characteristics of the peer-group; and iii) correlated (unobservable influences, i.e. random) effects refer to the observation that farmers in the same group tend to behave similarly because of similar individual characteristics or institutional constraints. Following these findings, the cost of compliance for farm $i$ are (beside others) a function of individual attitudes and experiences, whereas the latter can be modelled as a function of different factors based on social interaction. Following the notation above, the landowner's attitudes and experiences towards scheme *j* are described by

$$att_{ij} = G(pg_{ik}, t_{ik}, l_{ik}, v_{ik})_j \quad (8)$$

where *pg*, *t* and *l* are observable (measurable) and varying on farm *i* and peer-group level *k*, *v* is a random term. *pg* refers to endogenous effects, as e.g. peer-group or neighborhood based influences; *t* and *l* refer to exogenous effects, as e.g. time and space related influences affecting the individual farmer and his peer-group in the same way. The random influences *v* consist of unobservable effects *v* refering to the notion that farmers belonging to the same "group" tend to show similar behavioural patterns as a function of similar individual characteristics and/or structural and/or institutional constraints (e.g. similar past experiences with respect to such schemes and farming practices, similar structural farming conditions, similar exposure to policy/social events at the same point in time etc.), as well as $\omega$ denoting other general stochastic influences affecting the specific attitudes of farmer *i*

$$v_{ik} = v_{ik} + \omega_i \quad (9)$$

Hence, farm *i's* cost of compliance with the requirements of scheme *j* are

$$c_{ij} = F(m_i, tech_i, l_i, G(pg_{ik}, t_{ik}, l_{ik}, v_{ik}), \varphi_i)_j \quad (10)$$

with

$$\varphi_i = u_{ik} + \varepsilon_i = v_{ik} + \omega_i + \varepsilon_i \quad (11)$$

*Risk*

As summarized above, different studies on environmental services and agri-environmental policy schemes point to the relevance of risk for the landowner's decision to comply with the scheme's requirements. The basic compliance decision is modelled by assuming a risk-neutral farmer where the cost of compliance are only determined by the penalty for non-compliance and the probability of being detected (e.g. Heyes 1998). However, more detailed studies show that there is a functional link between the individual farmer's attitude towards production risk (due to input, output, technology, or market factors), his compliance behaviour, and the monitoring and enforcement costs of the conservation agency (Ozanne et al 2001, Fraser 2002 and 2004, Peterson and Boisvert 2004, Zabel and Roe 2009). The general notion is that the higher the risk aversion of the farmer and the higher the uncertainty faced with respect to his production income, the lower the costs for the conservation agency. Knowledge about farmers'risk preferences leads to lower agency costs via more effective scheme design based on targeted compliance incentives.

We assume that risk averse farmers participating in scheme *j* utilize a vector of inputs **x** to produce an output q through a technology described by a well-behaved - continuous and twice differentiable - production function *f(·)*. The individual farmer is assumed to incur production risk as product yields and quality might be affected by external environmental random variations but also by technology underperformance or failure. Such risk can be considered as being part of the random variable $\varepsilon$ with its distribution *H(·)* which is exogenously determined. Scheme participants can be assumed to be price-takers in both the input and output markets as the relevant scheme usually targets a relatively small and homogenous geographic area and hence factor price variability is low (Huffmann and Mercier 1991). Farmers in Europe further face minimum guaranteed output prices still regulated by the different commodity regimes of the EU Common Agricultural Policy. As outlined above farm *i* is subject to a regulatory standard which forbids it from using a detrimental input $ch_i$ beyond some level *s*. The efficiency of input *ch* use critically depends on the utilized technology and can be captured by incorporating a function $\psi(\alpha)$ in the production function $q = f[\psi(\alpha)x_{ch}, \mathbf{x}]$ where $\alpha$ is a vector of heterogeneous farm and farmer characteristics. Following Kountouris et al (2006) based on Antle (1983 and 1987), the risk averse farmer maximises the expected utility of profit $\varpi$ described by (12)

$$\max_{\mathbf{x},x_{ch}} E[U(\varpi)] = \max_{\mathbf{x},x_{ch}} \int \{U[pf(\mathbf{x}, \varphi(\alpha)x_{ch}, \varepsilon) - \mathbf{r}'\mathbf{x} - r_{ch}x_{ch}]\} dH(\varepsilon) \quad (12)$$

where *U(·)* is the von Neumann-Morgenstern utility function, and *p* and *r* as the non-random output and input prices respectively. The first-order condition for the detrimental input choice is given by

$$E[r_{ch}U'] = E\left\{p\frac{\partial f(\varepsilon,\varphi(\alpha)x_{ch},\mathbf{x})}{\partial x_{ch}}U'\right\} \Leftrightarrow \frac{r_{ch}}{p} = E\left\{\frac{\partial f(\varepsilon,\varphi(\alpha)x_{ch},\mathbf{x})}{\partial x_{ch}}\right\} + \frac{cov[U';\frac{\partial f(\varepsilon,\varphi(\alpha)x_{ch},\mathbf{x})}{\partial x_{ch}}]}{E[U']} \quad (13)$$

with $U' = \partial U(\varpi)/\partial\varpi$ and with the first term on the right-hand side denoting the expected marginal product of the detrimental input, and the second term measuring deviations from risk-neutral behaviour in the case of assumed risk-aversion (Antle 1987). Hence, risk faced by the farmer and his risk related behaviour affects his cost of compliance $c_i$ via the vector of technological characteristics **tech** including the farmer's choices regarding the detrimental input $ch_i$.

*Empirical Evidence*

Finally, with respect to empirical evidence on the performance of environmental services schemes and in particular agri-environmental schemes only a few studies exist so far. However, nearly all focus on the question of factors for adoption/participation in such schemes: Vanslembrouck (2002) explores the willingness of Belgian farmers to participate in two voluntary agri-environmental schemes and found that beside production decisions and especially farm size also the farmers' attitudes, age, education and neighbouring effects positively affect the probability to join. Cooper (2003) simultaneously estimates farmers' decisions to accept incentive payments for adopting environmental scheme practices. He concludes that the farmers' perceptions of the desirability of various bundles change with the offer amounts and with which practices are offered in the bundle. Hynes and Garvey (2009) model the participation decision by a random effects logit model using a large panel for Irish farmers. Their results point to the fact that systems of farming that are more extensive and less environmentally degrading remain those most likely to participate in the conservation scheme. In addition, the results highlight the fact that where no attempt is made to control for unobserved heterogeneity or path dependency the effects of the farm- and farmer-specific characteristics may be overestimated. Chang and Boisvert (2009) find statistical evidence that decisions to participate in a conservation program and work off the farm are correlated. Characteristics of farm households and farm operations affect both decisions directly and indirectly, as do local economic conditions and participation in other farm programs. Quillerou and Fraser (2009) investigate the adverse selection problem in the context of the UK Higher Level Scheme (HLS) as part of the Environmental Stewardship Scheme (ESS). It is found that, at the regional level, the enrolment of more land from lower payment regions for a given budget constraint has led to a greater overall contracted area reducing the adverse selection problem. Peterson and Boisvert (2004) provide the only empirical study so far that tackles the estimation of risk on farm level and its influence on participants' compliance behaviour and agency's scheme costs.

## 3 - Costs of Agri-Environmental Schemes

Several studies aim to shed empirical light on the performance of voluntary agreement type agri-environmental schemes, especially with respect to the relative financial efficiency or cost-effectiveness of such instruments (see Whitby and Saunders 1996, McCann and Easter 1999, Falconer and Whitby 2000, Falconer et al 2001, McCann et al 2005).[9]

*Space*

Spatial dimensions and environmental performances are not independent. The cost effects of space have been acknowledged by different contributions. Canton et al (2009) emphasise that a possible explanation of the great diversity in geographic coverage and scale of implementation of actual AES lies in the spatial heterogeneity of environmental impacts. Others stress that spatial targeting of agri-environmental schemes is justified by cost-effectiveness arguments (Wu and Babcock 2001 or Wuenscher et al. 2008) and the need to tailor AES to the specific conditions prevailing in a given area (OECD 2003). Further spatially determined (dis)economies of size with respect to administrative and transaction costs have to be considered (Falconer et al. 2001). Waetzold and Drechsler (2005) highlight that the criterion of cost-effectiveness calls for spatially heterogeneous compensation payments as the costs and benefits of biodiversity-enhancing land-use measures are subject to spatial variation. Canton et al (2009) show that such spatial targeting can be used by the conservation agency or regulator to reduce the effects of asymmetric information. Delegation of the implementation of AES to sub-national authorities can then be seen as a means of improving the regulator's ex-ante information.

*Transaction Costs*

Coase (1960) was the first to relate the concept of transaction costs to environmental policy evaluation. Different other authors note that the magnitude of such transaction costs involved with eliminating externalities is affected by the number and diversity of agents, available technology, type of instrument, the size of the transaction, and the institutional environment (e.g. Williamson 1985, Oates 1986, North 1990, Vatn and Bromley 1994, Stavins 1995, Challen 2000, Vatn 1998 and 2001). McCann and Easter (1999) note that in order to be incorporated in policy evaluation, transaction costs must be measured. The literature suggests that transaction costs of environmental policies are likely to be significant.[10] Nontrivial magnitudes mean that transaction costs will affect the optimal choice and design of policy instruments (McCann et al 2005). Although the magnitudes of transaction costs associated with environmental and natural resource policies are demonstrably important (Kuperan et al. 1998, McCann and Easter, 1999 and 2000, Falconer et al. 2001), few studies to date have attempted to actually quantify transaction costs.

McCann et al (2005) stress that transaction costs have in the past been viewed as wasteful and as something to be minimized. However, there are likely to be efficient versus inefficient types and magnitudes of transaction costs, analogous to efficient and inefficient combinations of inputs in a production process. To fully compare alternative policy instruments, policy choice and policy design should take account of the transaction (including administrative) costs involved, as well as production and abatement costs. Numerous definitions of transaction costs are available in the literature. As we aim to evaluate policy instruements, we define the term transaction costs as including administrative costs (see also Stiglitz 1986, Stavins 1995, McCann et al 2005). Such administration costs have resource use implications in both the public and the private sectors (see Spash/Simpson 1994, Hepburn 2006). Based on Allen (1991) and McCann et al (2005) we define transaction costs as resources used to design, establish, maintain, and transfer property rights.

Different types of costs may be borne by different conservation agencies or at different points in the policy instrument's life cycle (see table 1). Different types of policy instruments may entail a different mix of costs or a difference in the costs' relative importance. A number of transaction cost typologies exist in the literature (Dahlman 1979, Stiglitz 1986, Foster and Hahn 1993, Thompson 1999), however, any relevant framework has to be general enough to include both market and nonmarket policy instruments (Coase 1960). The following analysis focuses on the direct set-up and operating costs of policy instruments. As Falconer et al (2001) point out, voluntary management agreements require substantial levels of farmer/agency transacting, and some agreement costs show both fixed and variable components. For example, the negotiation costs for participants include a fixed cost of contacting with the conservation agency implementing the scheme, to indicate the farmer's wish to negotiate participation. However, there is also a degree of variability to costs as the scope of negotiation will vary with farm size and location, as e.g. with respect to proxy the range of habitats found there. Table 1 summarizes the different types of transaction costs related to the implementation of an agri-environmental scheme. The total costs of an agri-environmental scheme include beside these transaction costs also the actual compensation payments made to the farmers taking part in the scheme.

Table 1 - Transaction Cost Components for Agri-Environmental Schemes

| Category | Component | Sub-Component |
|---|---|---|
| set-up | 1) research / information | - surveying of the designated scheme area |
| | 2) design | - area designation and requirements design<br>- re-design/re-notification of requirements |
| | 3) enactment / litigation | - enactment of enabling legislation, lobbying and public |

| | | |
|---|---|---|
| | | participation<br>- changing laws or modifying existing regulations |
| administration | 4) contracting | - scheme promotion to potential participants<br>- negotiation between agency and participants |
| | 5) contracts' administering | - contract administration (especially transfer of payments) |
| monitoring | 6) inspection of contractors / non-compliance detection | - controlling at participants' premises and land |
| | 7) enforcement of requirements | - legal enforcement of participants' scheme compliance |
| evaluation | 8) scheme analysis | - research/information with respect to environmental effects<br>- static and dynamic monitoring and analysis |
| | 9) scheme evaluation | - overall evaluation of policy instrument |

(extension of Falconer et al 2001 and McCann et al 2005)

Most studies of transaction costs and environmental policy to date have either compared transaction costs qualitatively (Easter 1993), used the cost savings as an upper bound on transaction costs (O'Neil 1980, Williamson 1993), arbitrarily plugged a range of transaction costs into a model (Netusil and Braden 1995), assumed transaction costs to be some constant proportion of taxes raised (Smith and Tomasi 1995), suggested the difference between buying and selling price for pollution permits as a measure of transaction costs (Stavins 1995b), or examine past governmental costs for similar policies (Falconer et al 2001). Alternatively one could directly obtain estimates of transaction costs by means of surveys or interviews of government agency personnel (Fang et al 2005, Thompson 1996, McCann/Easter 1999). In the area of agri-environmental policy analysis, government figures have been used by a number of researchers (e.g. Falconer and Whitby 1999, McCann and Easter 2000, Falconer etal 2001). However, the major problem remains effective and timely access to such data.[11] Government documents could be used to develop estimates of transaction costs of public policies (Falconer and Saunders 2000).

*A Simple Scheme Cost Model*

So far there is no contribution which empirically investigates the link between conservation scheme costs and farmers' behaviour as well as farms' technological characteristics and spatial differences. Existing quantitative studies on the cost-effectiveness of agri-environmental schemes consider only scheme related factors and neglect variation over farmer behaviour, farm types and space.[12] Let *TC* denote the sum of all scheme *j* related transaction cost components as outlined in table 1 - fixed and variable costs for the set-up (*SU*), administration (*A*), monitoring (*M*), and scheme evaluation (*E*) for the time period t = 1, ...., T:

$$TC_{jt} = \sum_{t=1}^{T}(SU_{jt} + A_{jt} + M_{jt} + E_{jt}) \quad (14)$$

The total scheme costs *SC* (or exchequer relevant costs)[13] for scheme *j* in year *t* comprises compensatory payments *CP* and the sum of transaction costs *TC* and is a function of scheme related factors *sr* and factors related to scheme *j's* farmers' compliance behaviour *c*

$$SC_{jt} = CP_{jt}(sr_{jt}) + TC_{jt}(sr_{jt}, c_{jt}) = F_{jt}(sr_{jt}, c_{jt}) \quad (15)$$

Following equation (7) farmers' costs of compliance *c* are a function of managerial skills (*m*), technological characteristics (*tech*), spatial differences (*l*) but also individual attitudes and experiences (*att*). Scheme related factors are such related to the area under agreement (*aagr*), the number of agreements (*nagr*), the scheme age (*st*), other scheme specific characteristics (*z*), and potential overlap of the covered area with other agri-environmental instruments target area (*in*) as e.g. other conservation schemes and/or pollution taxes. Abstracting from *j* and *t*, we obtain

$$SC = F(aagr, nagr, st, z, in, m, tech, l, att) \quad (16)$$

The vector of technological characteristics (i.e. input/output levels and interactions) includes also the choices with respect to detrimental inputs (as e.g. chemicals, fertilizer), labor input allocation to the production of different outputs including beside marketed outputs also the ecosystem service compensated by the scheme, and land use decisions. The input and output decisions can be approximated by the first and second order derivates of the different outputs and with respect to the different inputs and outputs. Further by information on the focus and economic efficiency of the farm. To elicitate proxies for these technological characteristics and performance measures a multi-output framework can be used. Such a function in general form can be written as $0=F(\mathbf{Y},\mathbf{X},\mathbf{T})$, where **Y** is a vector of outputs (marketed and ecosystem services), **X** is a vector of inputs (including also detrimental inputs), and **C** is a vector of (external) shift variables, which reflects the maximum amount of outputs producible from a given input vector and external conditions. The model can be described as:

$$Y_{P,it} = F(Y_{it}, X_{it}, C_{it}, V_{it}, U_{it}) \quad (17)$$

where the subscript P denotes the primary output of farm i at time t. By adding $\boldsymbol{V}_{it}$ as a vector of random errors following iid N(0, $s_v^2$), and $\boldsymbol{U}_{it}$ ~N($m_{it}$, $s_u^2$) as a vector of inefficiency terms (see Battese and Coelli 1995) a transformation frontier is obtained. The empirical estimation of (17) yields an efficiency estimate per farm and year ($eff_{it}$) as well as first order derivatives ($\varepsilon_{P,S}$; $\varepsilon_{P,k}$) to approximate the farmers' input *k* and output *S* choices as well as his cost of compliance with scheme *j*.

Following the discussion above, to obtain valid proxies for the farmers' specific production risk we can describe a profit function for each farm *i* at time *t*. Hence, profit per farm and year $\varpi$ as a function of variable input prices ***R*** (including also prices of detrimental inputs), relevant output prices ***P***, and a vector of extra profit shifters ***C*** as well as an iid error term ***V***:

$$\omega_{it} = F(R_{it}, P_{it}, C_{it}, V_{it}) \quad (18)$$

The estimated moments ($\mu_o$) of the profit function in (18) can be used as proxies for the individual farmer's production risk[14] and deliver empirical evidence on his risk related behaviour, hence, also his compliance behaviour with scheme *j's* contractual requirement. Using the estimates for farm *i's* production risk, technical and scale efficiency, and input and output elasticities to further specify the cost structure of conservation scheme *j*, as well as considering equation (8), we get

$$SC = F[aagr, nagr, st, z, in, m, tech(\mu_o, \text{eff}, \varepsilon), l, att(pg, t, l, v)] \quad (19)$$

If the total scheme costs *SC* for scheme *j* and year t are compared to the total scheme costs *SC* for scheme *j* in year t+1 differences in the scheme's overall rate of compliance have to be considered. This can be done by weighting the total scheme costs by the rate of compliance in the specific year ($SC_c$)

$$SC_{c,jt} = F(\cdot)_{jt} \quad (20)$$

To make inferences at the relevant administrative scheme level (i.e. to adequately reflect budget authority) we consider the scheme costs e.g. at the regional (i.e. subnational) level (*gor*)

$$SC_{c,gor,jt} = F(\cdot)_{gor,jt} \quad (21)$$

Finally, to consider the environmental effects side of the scheme - in terms of a cost-effectiveness type perspective - we can use a proxy for the sum of environmental effects per space unit (e.g. per ha land covered) and re-write our total scheme cost function as an average scheme cost function or scheme cost per ha function

$$\left(\frac{SC_c}{ha}\right)_{gor,jt} = F(\cdot)_{gor,jt} \quad (22)$$

Different hypotheses regarding specific cost factors can be investigated by estimating (22) and interpreting the individual parameters estimated for the elements of F(·).

## 4 – Empirical Example: The Environmental Stewardship Scheme (ESS) in the UK

Agri-environmental schemes (AES) have become the dominant instrument of EU agri-environmental policy (Latacz-Lohmann and Hodge 2003), with EU expenditure on agri-environmental measures increasing to more than EUR 2 billion in 2005 and agri-environmental contracts covering more than a quarter of the EU-25 utilized agricultural area (European Commission 2008). By participating in AES contracts, farmers voluntarily commit themselves to adopting practices that go beyond the minimal practice of "good farming". In return, they are entitled to payments meant to compensate incurred costs and foregone income (Canton et al 2009). The Environmental Stewardship Scheme (ESS) has been launched in mid 2005 and replaces the previous UK agri-environment schemes. It consists of an entry-level (ELS) and a higher-level (HLS) scheme, whereas the entry-level scheme has also an organic strand. The ESS is an example of the 'wide-and-shallow' approach replacing the more targeted schemes that were in place since the mid eighties (Dobbs and Pretty 2004 and 2008, Defra 2005).[15]

As part of the Environmental Stewardship Scheme, agricultural producers agree to modify their production activities to benefit the environment and are compensated for the costs they so incur. Most modifications imply a reduction in the intensity of production and the loss is usually conceived as income foregone by profit-maximizing producers. The level of compensation offered must be sufficient to persuade producers to forgo production options and to replace the income they lose. The ELS part of the ESS is largely untargeted geographically which has resulted in significant sectoral and associated geographical variations in the level of ELS agreement uptake (see appendix, figure A1 and mapA1). There is a low uptake of certain options, a significant proportion of agreement holders are choosing a limited number of options resulting in imbalanced agreements (between field boundary and in-field options and across scheme objectives). The choice of options often does not match well with policy priority options for a given area (Chaplin 2009).[16] These findings stress the need for an analysis of the performance of the ESS instrument at the scheme cost relevant level, i.e. at the level of UK government office regions ('GOR' level).

## 5 – Empirical Methodology

To the background of the theoretical considerations and earlier empirical findings we formulate the following research hypotheses:

(1) The average scheme costs significantly vary at a regional level.

(2) The scheme costs significantly vary over time at the regional level. The enrolment of more land from lower payment regions has led to a reduction in the adverse selection problem in some regions.

(3) Scheme related characteristics (i.e. number of agreements, relative density of agreements) show a considerable influence on the cost structure, e.g. via (dis)economies of scale/size or administrative learning.

(4) The compliance rate across all farms participating in the scheme is directly linked to the scheme costs. Farms differ in how costly they find it to comply. This might reflect differences in management skills and attitudes, production focus, location, or technologies. Hence, we expect that:

   a. Socioeconomic characteristics of the participating farms/farmers have a significant effect on the cost-effectiveness of the instrument - farmers' attitudes, age, education and neighbouring effects. Further, the decision to participate in a conservation program and work off the farm are correlated: Characteristics of farm households and farm operations affect both decisions directly and indirectly.

   b. Risk related characteristics of the participating farms/farmers show a significant effect on the cost-effectiveness of the instrument. Risk averse farmers who face uncertainty in their production income are more likely to comply with agri-environmental schemes as a means of risk management. There is a functional link between the individual farmer's attitude towards production risk, his compliance behaviour, and the monitoring and enforcement costs of the conservation agency.

   c. The technological characteristics and economic performance of the participating farms have a significant effect on the cost-effectiveness of the instrument. Production systems that are more extensive and less environmentally degrading remain those most likely to participate in the conservation scheme.

   d. Spatial heterogeneity of environmental impacts and the environmental performances of participating farms are dependent. Hence, spatial variation in environmental characteristics of the participating farms has a significant effect on the cost-effectiveness of the instrument.

(5) The share of participating farms also participating in other environmental service schemes has a considerable influence on the cost structure of the scheme(s), e.g. via

(dis)economies of scope, administrative learning, and joint production decisions at the farm level.

By empirically investigating the validity of these hypotheses, we aim to contribute to the literature in the following ways: There are still only a very few empirical studies available investigating the performance of environmental schemes using microdata at the farm level. We control for the actual level of compliance per region by using compliance weighted average scheme cost ratios. Beside technological and economic performance measures, we also consider proxies for risk at farm level. By this we go further than existing studies on environmental schemes and aim to empirically investigate the theoretically well explored policy implications of adverse selection and moral hazard. In addition we consider unobserved heterogeneity or path dependency with respect to unknown spatial and farm specific factors. Hence, we try to disentangle random and fixed scheme cost effects by applying a mixed-effects estimation approach.

*Data*

In contrast to earlier studies (see e.g. Falconer et al 2001) we were able to obtain annual data on the different transaction cost components with respect to all full years (2006 to 2008) the ESS scheme is in operation. Whereas the data on the conservation payments is at regional level, parts of the cost data are only available at the national level. Hence some weighted proxies are necessary to obtain cost data at the administratively relevant level of government office regions in England (i.e. East Midlands, East of England, London, North East, North West, South East, South West, West Midlands, Yorkshire and Humberside). The cost data as well as weighting procedures are based on staff communications and interviews (at Defra and Natural England) as well as internally recorded scheme performance data, hence, consists of expert informed proxies and calculations. We us different weights to build cost proxies at the regional level: share of payments for region $g$ (cost proxy 1), share of live agreements for region $g$ (cost proxy 2), share of total agreements created for region $g$ (cost proxy 3). Finally we build an average cost proxy across these ratios (cost proxy 4).

To reflect also the effects side of the instruments we further divide the cost by the total area under the scheme for region $g$ to obtain cost-effect or average cost ratios per ha area covered per region (cost ratio 1 to cost ratio 4). Finally, to adequately reflect the actual area under the scheme – i.e. adjusting for non-compliance by weighting the area under agreement by the recorded compliance rate per region and year – we build compliance weighted cost-effect or average cost ratios per ha area covered per region (cost ratio 1c to cost ratio 4c). The detailed calculations are reported in the appendix A1. As the number of regions and years indicate a likely small sample bias we bootstrap the descriptive statistics to obtain evidence on the robustness of the sample statistics (table A1 in the appendix gives a brief summary of the bootstrapped statistics for the different cost ratios). By using such scheme cost data we overcome data limitations faced by earlier studies with respect to the number of agreement enquiries that failed to result in a signed management agreement, the area entered into different options, the geographical diffusion of participating farmers, and their attitudes and risk exposure as well as compliance behaviour per region and year.[17] Hence, our cost data reflects the actual administrative effort to be required for efficient scheme running to a large degreee as this depends on how well farmer participation and administrative resource needs are forecasted. For the estimation of risk, technological characteristics and economic performance we use data on farm level contained in the Farm Business Survey provided annually by Defra. Our extracted sample consists of all farms participating in the ESS scheme across England in the years 2006 to 2008 (see table A2 to A4 in the appendix for further information).

*Modelling I: Estimating Risk Proxies*

To obtain valid proxies for the farmers' specific production risk we estimate a flexible profit function for the farms I at time T in the sample (see e.g. Christensen and Lau 1973). Hence, we first regress profit per farm and year $\varpi$ on a vector of variable input prices $\boldsymbol{R}$ (labor, land, fodder, veterinary & medical services, fertilizer, seeds, chemicals, capital), the relevant output price *P* (i.e. depending on robust type either milk price, livestock unit value, crop unit value, or an aggregated output price measure), and a vector of extra profit shifters ***C*** (time trend, farm type, farmer's age, debt ratio, rental value/gross margin, total subsidies/gross margin, less favoured area, degree of specialisation, government office, county location, off-farm income, altitude, area under the Nitrate Vulnerable Zone scheme) as well as an iid error term *v*:

$$\omega_{it} = \varphi(\mathbf{R}_{it}, P_{\mathrm{it}}, \mathbf{C}_{it}; \beta) + v_{it} \quad (23)$$

Assuming profit maximisation we use the flexible functional form of a translog function and estimate in a first step the following model:

$$ln\omega_{it} = \alpha_0 + \sum \alpha_j lnR_{ij} + \alpha_l lnP_{il} + 1/2 \sum \alpha_{jk} lnR_{ij}\, lnR_{ik} + 1/2 \sum \alpha_{jl} lnR_{ij}\, lnP_{il} + \sum \beta_m\, C_{im} + v_{it} \quad (24)$$

where $v \sim N(0, \sigma^2)$. Applying ordinary least squares provides consistent and efficient parameter estimates.[18] The *o*-th central moment of profit conditional on input use is defined as

$$\mu_o(\cdot) = \overline{E}\{[\omega(\cdot) - \mu_1]^o\} \quad (25)$$

where $\mu_1$ denotes here the mean of profit. Thus, the estimated errors from the mean effect regression ($\hat{v} = \omega - \varphi(\cdot)$) are estimates of the first moment of the profit distribution. These are squared and regressed on the set of explanatory variables from (24), which gives

$$\hat{v}_i^2 = \vartheta(\mathbf{r}_{it}, p_{\mathrm{it}}, \mathbf{c}_{it}; \delta) + v_{it} \quad (26)$$

By using again OLS on (26) we obtain consistent and efficient estimates of the variance (2[nd] moment). This procedure is followed to estimate also the third (i.e. skewness) and fourth (i.e. kurtosis) central moments based on the estimated errors raised to the power of three and four, respectively, used as dependent variables (see Antle 1983 and 1987, Kountouris et al 2006). The estimates obtained for the four moments are used as proxies for the individual farmer's production risk by incorporating them directly into models of average cost regressions along with other explanatory variables. The model in (24) is estimated by applying Maximum Likelihood treating the dataset as an unbalanced panel.

*Modelling II: Estimating Technological Characteristics and Economic Performance*

To obtain estimates of the production structure and performance of each farm we further estimate a flexible transformation function in a frontier specification (see e.g. Diewert 1973, Morrison-Paul and Sauer 2009). Such a transformation function is desirable for modeling technological processes because multiple outputs are produced by UK farms precluding the estimation of the technology by a production function, yet we wish to avoid the disadvantages of normalizing by one input or output as is required for a distance function.[19] We thus rely on a transformation function model representing the most output producible from a given input base and existing conditions, which also represents the feasible production set. This function in general form can be written as $0=F(\mathbf{Y},\mathbf{X},\mathbf{T})$, where **Y** is a vector of outputs, **X** is a vector of inputs, and **C** is again a vector of (external) shift variables, which reflects the maximum amount of outputs producible from a given input vector and external conditions. By the implicit function theorem, if $F(\mathbf{Y},\mathbf{X},\mathbf{C})$ is continuously differentiable and has non-zero first derivatives with respect to one of its arguments, it may be specified (in explicit form) with that argument on the left hand side of the equation. Accordingly, we estimate the transformation function $Y_1= G(\mathbf{Y}_{-1},\mathbf{X},\mathbf{C})$, where, $Y_1$ is the primary output of the farm and $\mathbf{Y}_{-1}$ the vector of other outputs (secondary output), to represent the technological relationships for the farms in our data sample. Note that this specification does not reflect any endogeneity of output and input choices, but simply represents the technologically most $Y_1$ that can be produced given the levels of the other arguments of the F(•) function (see also Morrison-Paul and Sauer 2009).

We approximate the transformation function by a flexible functional form (second order approximation to the general function), to accommodate various interactions among the arguments of the function including non-constant returns to scale and technical change biases. A flexible functional form can be expressed in terms of logarithms (translog), levels (quadratic), or square roots (generalized linear). We use the generalized linear functional form suggested by

Diewert (1973) to avoid any mathematical transformations of the original data.[20] The model can be described as:

$$Y_{P,it} = F(Y_{it}, X_{it}, C_{it}) = \alpha_0 + 2\alpha_{0S}Y_S^{0.5} + \sum 2\alpha_{0k}X_k^{0.5} + \alpha_{SS}Y_S + \alpha_{kk}X_k + \sum \alpha_{kl}X_k^{0.5}X_l^{0.5} +$$
$$+ \sum \alpha_{kS}X_k^{0.5}Y_S^{0.5} + \beta_t T + \beta_{tt}T + \sum \beta_{kt}X_k^{0.5}T + \sum \beta_{kt}X_k^{0.5}T + \beta_{St}Y_S^{0.5}T + v_{it} - u_{it} \quad (27)$$

for farm i in time period t, where $Y_P$ = primary agricultural output, and $Y_S$ = secondary output (i.e. total agricultural output less primary output) as the components of $\mathbf{Y}_{-1}$, **X** is a vector of $X_k$ inputs as outlined above, and a time trend T as the only component of the **T** vector. $V_{it}$ is assumed to be iid $N(0, s_v^2)$ random errors, and $U_{it} \sim N(m_{it}, s_u^2)$ as the inefficiency term per farm and year (see Battese and Coelli 1995). The model in (27) is estimated by using the Battese/Coelli (1995) estimator contained in Limdep 9.0 by treating the dataset as an unbalanced panel. The corresponding likelihood function and efficiency derivations are given in Battese and Coelli 1995 or Coelli et al 2005. To represent and evaluate the technological or production structure, the primary measures we wish to compute are first- and second-order elasticities of the transformation function.

Returns to scale are computed as a combination of the $Y_P$ elasticities with respect to the other output and inputs. A measure of scale efficiency can then be obtained by simply calculating the ratio of the individual farms' efficiencies for the constant and variable returns to scale frontier $\rho_{it} = u_{P,X,crs}/u_{P,X,Vrs}$. Technical change is measured by shifts in the overall production frontier over time. As our only technical change variable is the trend term T, productivity/technical change is estimated as the output elasticity with respect to T.

*Modelling III: Estimating Scheme Cost Effects*

The previously calculated average cost ratios are used to estimate the cost-effectiveness of the ESS scheme on a regional level within a regression framework. Following equation (16) the different cost ratios are regressed on: **A** as a vector of ESS scheme agreements characteristics on regional level, **F** as a vector of technological characteristics and economic performance measures on farm level, **R** as a vector of risk proxies, **S** as a vector of individual farmer characteristics, **E** as a vector of environmental conditions including spatially defined characteristics. We define a simple linear model:

$$CER_{it} = \alpha_0 + \sum \epsilon_j A_{ijt} + \sum \theta_k E_{ikt} + \sum \zeta_l F_{ilt}^* + \sum \eta_o R_{iot}^* + \sum \vartheta_q S_{iqt} + v_{it} \quad (28)$$

for farm i in time period t, where **A** = total number of ESS agreements, density of ESS farms in GOR, year 2007 (dummy), year 2008 (dummy); **F** is a vector of production characteristics: the main production focus of the farm (cereals, general cropping, horticulture, pigs, poultry, dairy, lfa grazing livestock, grazing lowland, or mixed), elasticities of primary farm output with respect to secondary output and all inputs, the rate of technical change, the relative technical efficiency of the farm, farm size, the scale efficiency of the farm, the profit per ha, off-farm income, debt per assets; **R** as a vector of risk proxies: expected profit mean, profit variability, profit asymmetry, profit peakedness, expected profit mean over time, profit variability over time, profit asymmetry over time, profit peakedness over time; **S** as a vector of individual farmer characteristics: age of the farmer, gender of the farmer; **E** as a vector of environmental conditions including spatially defined characteristics: share of farm land under NVZ scheme, income from hill farm allowance scheme, altitude1 (most of land at 300-600m), altitude2 (most of land at >600m), lfa1 (all land inside sda), lfa2 (all land inside da), lfa3 (50%+ in lfa, of which 50%+ in sda), lfa4 (50%+ in lfa, of which 50%+ in da), lfa5 (<50% in lfa, of which 50%+ in sda), lfa6 (<50% in lfa, of which 50%+ in da), government office region, and county. The elements of **R*** as well as some of the elements of vector **F*** are estimates resulting from the estimation of the flexible profit function (modelling step 1) and the estimation of the transformation frontier (modelling step 2).

As some of the covariates are grouped according to one or more characteristics (i.e. representing clustered, and therefore dependent data with respect to regional, county, and farm level) we apply a multi-level modelling approach commonly referred to as mixed-effects or hierarchical model (see e.g. Fox 2002, Bryk and Raudenbush 2002). Such a mixed model is characterized as containing both fixed and random effects: The fixed effects are analogous to standard regression coefficients and are estimated directly. The random effects are not directly estimated but are summarized according to their estimated variances and covariances. Random effects may take the form of either random intercepts or random coefficients, and the grouping structure of the data may consist of multiple levels of nested groups (here related to government office region, county and individual farm). The error distribution of the linear mixed model is assumed to be Gaussian. Abstracting from time period T the Laird and Ward (1982) form of the model outlined before would then be

$$CER_{im} = \alpha_0 + \sum \epsilon_j A_{ijm} + \sum \theta_k E_{ikm} + \sum \zeta_l F^*_{ilm} + \sum \eta_o R^*_{iom} + \sum \vartheta_q S_{iqm} + \sum b_{iw} Z_{wim} + v_{im} \qquad (29)$$

with $b_{iw}$ ~iid $N(0, \xi_b^2)$, $cov(b_w, b_{w-1}) = \xi_{w,w-1}$, $v_{im}$~iid $N(0, \sigma^2\lambda_{mii})$, $cov(v_{mi}, v_{mi-1}) = \sigma^2\lambda_{mii-1}$. $CER_{im}$ is the value of the response variable for the i-th observation in the m-th group of clusters; $\epsilon_j$, $\theta_k$, $\varsigma_l$, $\eta_o$, $\vartheta_q$ are the fixed-effect coefficients which are identical for all groups; $A_{ijm}$, $E_{ikm}$, $F^*_{ilm}$, $R^*_{iom}$, $S_{iqm}$ are the fixed-effect regressors for observation i in group m; $b_{iw}$ are the random-effect coefficients for group m, assumed to be multivariately normally disctributed and varying by group; $b_{iw}$ are designed as random variables and are hence similar to the errors $v_{im}$; $Z_{iwm}$ are the random-effect regressors, $\xi_b^2$ and $\xi_{w,w-1}$ are variances and covariances among the random effects assumed to be constant across groups; $v_{im}$ is the error for observation i in group m assumed to multivariately normally distributed; $\sigma^2\lambda_{mii-1}$ are the covariances between errors in group m. In our case, observations are sampled independently within groups and are assumed to have constant error variance ($\lambda_{mii}=\sigma^2$, $\lambda_{mii-1}=0$), and thus the only free parameter to estimate is the common error variance, $\sigma^2$. The model in (29) is estimated by maximum restricted (or residual) likelihood (REML) (see e.g. Harville 1977 for details of the likelihood function). As the dependent variable varies at regional level and the explanatories vary either at regional or farm level, we also estimated an ordered logistic mixed regression by transforming the cost data into categories of ratios using ordinal numbers. However, the estimation results showed no significant differences in sign and value with respect to the estimated coefficients, hence, we prefer and report the linear mixed-effects regression allowing for random effects based on different spatial groupings (i.e. government office region and county level).[21] We further run separate regressions for compensatory payments and scheme transaction costs. The estimates were not significantly different from those obtained by the combined total cost regressions, hence, we prefer and report the estimation results only for the latter.

Finally a bootstrap based resampled estimation procedure is applied to receive evidence on the statistical robustness of the estimated standard errors (see Efron and Tibshirani 1993, Horowitz 2001; details on the bootstrap estimator can be obtained from the authors upon request). By applying the outlined three-stage estimation procedure we significantly contribute to the literature by improving on earlier empirical studies. We simultaneously model fixed and (unobservable) random scheme cost effects by avoiding inconsistencies implied by other estimators (e.g. a within-group estimator applied by Falconer et al 2001). To avoid small sample bias and non-robust results (see Quillerou and Fraser 2009) we use a satisfactorily large sample for the full ESS scheme and a statistical resampling procedure.

## 6 - Results and Discussion

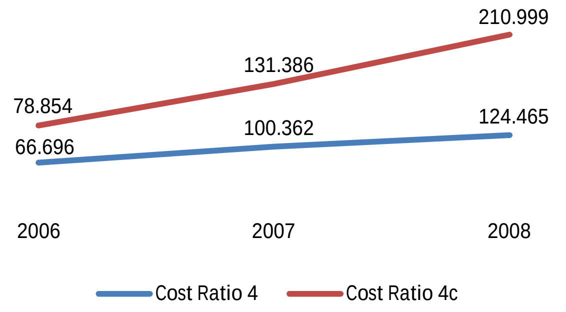
All models estimated show a reasonable overall statistical significance.[22] Additional diagnostic and quality tests have been conducted for the mixed-effects cost regressions and are reported in the appendix (see tables A6 and A7). In addition, the bootstrapped standard errors for the different cost ratios and estimated parameters show a high level of robustness over the sample. In general we found, that the average scheme costs significantly vary over space (government office regions, GOR) and time (years 2006 to 2008).

*Total Scheme Costs*

The bootstrapped cost ratios for different years show that there is an increase in the average scheme cost per ha over time (see appendix table A5. Figure 1 illustrates this for the cost ratios 4 and 4c (as the average over cost ratios 1 to 3) and figure 2 shows the yearly percentage changes in total cost per region, total scheme area per region, and total compliance rate per region. Cost ratio

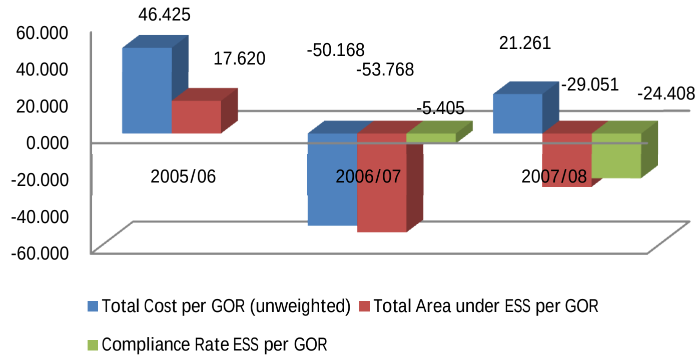
4c indicates that this increase is also driven by a decreasing compliance rate over all participating farms per region and year.

Figure 1 - Bootstrapped Mean Cost Ratios 4 and 4c for Different Years (GBP per ha)




(own calculations)

Figure 2 - Annual Changes in Total Cost, Total Area and Compliance Rate per Region (%)




(own calculations)

These descriptive findings are backed up by the estimated coefficients for the year dummies for 2007 and 2008. Both coefficients are significantly positive over all cost models estimated, i.e. that the costs per ha significantly increase over time, and to a higher extent in 2008. This could be due to an increasing number of farms accessing the scheme demanding payments to a higher degree than contributing land to the scheme. In addition the effective dissemination of knowledge about the scheme's existence and mechanisms over time due to learning by doing among participating farms as well as peer-group/spillover effects based on social interaction with other farms could play a role. Contrary to theoretical considerations these empirical findings suggest that despite the enrolment of more land from lower payment regions which might have led to a reduction in the adverse selection problem and, hence, lower payment costs in some regions (Quillerou and Fraser 2009), the total costs per ha area under the scheme increased in the years considered. This could be due to an increase in the administrative costs involved in setting-up and managing agreements. Falconer et al (2001) point out that the scheme costs are also expected to fall with years following scheme implementation due to administrative cost savings from fine-tuning and the learning processes that occur over time (leading the individuals and the administrations involved to learn to streamline processes, through building human capital, developing their understanding of the other transacting party etc.).

Furthermore, over time, changes in the mix of administrative activities are needed, linked to the time profile of the scheme take-up. Hence, after a few years, the balance will switch from set-up activities such as promoting the scheme and entering into contracts to more routine maintenance activities (e.g. making compensatory payments and checking compliance) whereas the latter would be expected to be less costly than the set-up activities. In addition, trade-offs between different types of sub-scheme expenditures may exist. For example, greater expenditure on scheme promotion and information dissemination may allow savings to be made with regard to negotiating or enforcing management agreements, given an improved understanding of requirements and objectives. Finally, idiosyncratic factors such as staff turnover or competence levels will affect administrative efficiency.

Our findings suggest that this point of the long-term cost curve has not been reached for the ESS scheme yet, especially if one takes into consideration the overall scheme's compliance rates (see cost ratio 4c). These findings also confirm the underlying assumption that unweighted scheme costs per region substantially differ from cost ratios taking into account regional differences with respect to agreements density and types of options per average agreement.

*Scheme Characteristics*

The cost model estimates further reveal that diseconomies of scale play a role with respect to the scheme's cost structure: The more scheme agreements per region, the higher the payments to farmers, the higher the costs per ha. However, the negative coefficient for the squared number of agreements indicate that cost savings at regional level could be reaped beyond a certain number of agreements under the scheme. Hence, a point on the cost function exists where economies of scale set in. Beyond this point an increase in the number of agreements would lead to decreasing average costs per ha. Reasons for such positive scale effects could be administrative cost savings from fine-tuning and the learning processes that occur with an increasing number of agreements, the effective use of administrative capacity and skills, and the cost effective use of monitoring technology as well as evaluation practices.

However, with respect to the density of agreements per region we found for the unweighted cost ratio a positive cost effect but a negative one for the weighted cost ratio. Diseconomies of agglomeration can be due to an average cost increase as a consequence of increased administration and monitoring efforts in densily populated farming areas. Falconer et al (2001) conclude, that scheme costs relate both to those farmers who actually participate, and to those who do not, i.e. costs may still be incurred in relation to the latter through answering inquiries and promotional activities by the implementing conservation agency. As the actual rate of compliance per region is considered (i.e. weighted models 5 to 8), however, economies of agglomeration were found with respect to the density of agreements per region. This suggests cost savings because of behavioural spill-over effects with respect to scheme participation and compliance. Hence, by cleaning the ratio with respect to actual compliers positive average cost effects can be found with respect to the regional density of complying agreement holders. Positive farmer attitudes towards conservation and the scheme might be linked to lower scheme transactions costs.

In addition the random effects intercepts incorporated with respect to unobserved variation over government office regions show a high statistical significance and large positive estimates for all cost models. This suggests that (unobservable) variation in administrative characteristics of the different administrative agencies on regional level has a significant effect on the cost-effectiveness of the instrument. Unobservable (and not quantifiable) scheme cost differences can relate to fine-tuning and learning processes that occur over time (leading the staff involved to learn to streamline processes, through building human capital, developing their understanding of the mechanisms and benefiting from social spill-over effects etc.). Previously mentioned idiosyncratic factors (e.g. staff turnover or differences in competence levels) also significantly affects variation in administrative efficiency.

*Socioeconomic Characteristics*

We found that socioeconomic characteristics of the participating farms have a significant cost effect. Throughout the estimated unweighted models (model 1 to 4) the age of the farmer is negatively linked to the average cost per ha, whereas a positive link is found for the weighted models (model 5 to 8). This indicates that age (and likely also farming experience) is a significant factor for scheme compliance: the younger the average paticipating farmer, the higher the average compliance rate per region, and consequently the lower the average scheme costs per region. These findings suggest that the individual cost of compliance are lower for younger farms which might reflect positive attitudes towards conservation or more cost effective management skills with respect to the requirements of the scheme. However, positive farmer attitudes towards conservation and the scheme might be linked to lower transactions costs. The broad co-operation of entrants with the agency would mean that environmental agencies could rely far more on self-enforcement, thus reducing compliance checks (see Falconer et al 2001).The positive age effect found for the unweighted models, however, could imply that older farmers show a higher interest in the scheme in general. In addition, those farmers located in less favoured areas and hence are more interested in agri-environmental schemes are of higher age as the probability of a younger successors is relatively low.

The amount of income generated by off-farm activities was found to be significantly negatively correlated with the average scheme costs for the compliance weighted and unweighted models. This shows that the decision to allocate labour to the conservation activities under the scheme agreement and the decision to allocate labour to off-farm activities are correlated. Farms that generate a higher amount of income by non-agricultural activities are more likely to comply with scheme requirements as less time and labor resources are available for hidden non-compliance related actions are available and/or a softer budget constraint exists. Further, the income effects of general production and market risk are less significant for such farms. With respect to the input land this could imply that the higher the share of total output due to off-farm income, the lower are the opportunity costs of using land for non-market uses, hence, the higher the willingness to give land under the scheme and finally the lower the scheme costs per ha. Also, the higher the share of total output due to off-farm income, the higher is the willingness of the farmer to comply with the conservation agreement as the opportunity costs of using land and other inputs for the scheme are even lower, hence, off-farm income increases compliance and decreases average scheme costs.

*Risk Related Factors*

The majority of estimated coefficients for the risk proxies show a significant influence on the average scheme costs investigated. We found that the higher the farmers' expected profit (i.e. the less significant the influence of production and market risk), the lower the average scheme costs per ha as the willingness/need to join the scheme to hedge against such risk effects decreases and hence the scheme costs related to compensation payments are lower. For the compliance weighted models this negative cost effect is less pronounced and suggests that risk averse farmers who face low uncertainty in their production income are less likely to comply with agri-environmental schemes as a means of risk management. A positive cost effect has been found with respect to profit variance (or the variability of the risk effects on mean profit) for the unweighted models implying that farmers use the scheme income as a means to hedge against such risk. However, with respect to the compliance weighted models the empirical evidence suggests that risk related profit variance leads to a higher average degree of scheme compliance, hence, more land is actually cultivated based on the agreements' requirements and consequently lower average scheme cost per ha. Further the results reveal, that the higher the expected upside profit variability (negative skewness estimate), the lower the significance of risk and the probability of loss, hence, the lower the willingness/need to join agri-environmental schemes to hedge against such risk. The fourth moment of the profit function (profit peakedness) shows a positive average scheme cost effect implying that the higher the probability of facing extreme profit values the higher the willingness of the farmer to hedge against such risk by scheme participation.

For the cross variables (risk moments and time) the estimates reveal the following insights: The negative cost effect by the expected mean profit is decreasing over time which could be due to an increased need to consider production risk as a result of policy changes (e.g. decoupling effects on expected profit). Secondly, the positive cost effect with respect to profit variability is increasing over time for the unweighted models. Beside an increase in market risk because of policy changes this could further imply that learning by doing and social interaction (peer-group and spillover effects) with respect to knowledge about the scheme's entry requirements could play a role. However, with respect to the compliance weighted models the results indicate that time enforces the negative cost effect of profit variability suggesting that an increase in profit risk leads to lower compliance over time. The effect of the third profit moment (profit skewness) on cost does decrease over time suggesting that farmers face increased profit risk due to policy changes in the years after the initial scheme introduction in 2005, hence, the need for risk considerations and alternative “risk-free” income is increasing. Finally, mixed results were found for the effect of time on the cost effect of profit peakedness: The unweighted estimates indicate an increase in the positive cost effect whereas the weighted estimates suggest a decrease in the cost effect by the probability of facing extreme profit values. It could be concluded, that over time farmers cost of scheme compliance decrease as the probability of extreme profit events increase (i.e. more land is actually cultivated based on the agreements' requirements and consequently lower average scheme cost per ha.

*Technology and Performance Related Factors*

The estimation results reveal a significant cost effect by technological and performance related characteristics of the farms under agreement. Testing for the significance of the type of farming operations (based on the FBS used categories) we found that a high share of cereal farms and a high share of pig farms per region is linked to higher average scheme costs per ha. As figure A1 (appendix) outlines: the uptake of the ELS scheme is the highest among cereal producers which explains the positive cost effect. Intensive pig producers show a medium uptake of the scheme. However, the positive cost effect for these farms could be due to the likely lower amount of hectares put under the scheme per agreement and the amount of fixed transaction costs related to the individual agreements negotiation regardless how area-intensive the agreements are. Although there is a menu of prescriptions with fixed payments rates, the precise "package" for any one farm is negotiable. There is of course some flexibility for farmers in relation to which prescriptions are included, and the amount of land to be covered by an agreement. An agreement with many different management options but only a low area included results in higher average costs per ha as an agreement based on only a few but area intensive options. We further found a negative average cost effect for upland/lfa grazing livestock farms as well as a negative average cost effect for lowland grazing livestock farms. These findings correspond to the actual uptake of the scheme. As these farms are likely to negotiate rather area-intensive agreements the total scheme costs per ha are lower for these regions.

Considering the production structure of the farms by taking a marginal perspective using output elasticities (here the primary output is considered) we obtain the following insights:[23] The higher the marginal contribution of the non-primary output at the point of current production – i.e. the less specialised the farm is – the higher are the average scheme costs. This is in line with the descriptive findings on the scheme uptake: mixed farms (defined by general FBS criteria) show a high uptake, hence, higher payment costs in these regions. The elasticity with respect to land has a positive cost effect which reflects the high scheme uptake among land intensive farms as those are the farms with the highest marginal contribution by the input land. This holds also for fertilizer and crop protection inputs as those inputs are complementary to land. The positive cost effect for the elasticity with respect to capital also reflects the high marginal contribution for those production lines which show the highest scheme uptake (cereals, cropping, and mixed farms). The elasticities with respect to fodder and veterinary expenses show to have a negative average cost effect which could reflect the low uptake among livestock intensive farms (grazing livestock, poultry, and pig farms).

The size of the farm has a positive effect on the average scheme costs which means that the payment effect outweighs the transaction cost effect with respect to the scheme's cost structure. Large farms show the highest uptake of the scheme, small farms the lowest uptake. However, the positive cost effect for large farms could simply reflect the fact that having a large number of small land-owners potentially eligible to enter the scheme in an area would be expected to entail more administrative work than if fewer land-owners were eligible. Further, we found that the average scheme costs per ha decrease as the farm's scale efficiency increases. Also, the higher the farm's profit per ha, the lower the scheme's average costs. This suggests that farms with a higher economic performance are those less willing to participate in the scheme as they are less dependent on risk free income. Those farms have effective risk copying strategies and management skills to sustain their efficient status relative or on the production frontier. This is backed up by the positive estimates for the debt to asset ratio. These findings may suggest adverse selection with respect to the farms participating in the scheme as those with a relatively lower economic performance are more likely to join and hence, average costs per ha are increasing because of scheme payments.

The rate of technical change and the technical efficiency of the farms, however, show differing results for the unweighted and weighted models: Whereas the cost effect is positive for the unweighted models, it is negative for the weighted models. Consequently, evidence for adverse selection is found only in the case of the compliance weighted cost ratios. However, this could suggest that farms with a higher relative performance are more likely to comply with the scheme requirements as these farms are less dependent on the land under the scheme. Finally, the degree of specialisation showed no significant cost effect which reflects the fact that more specialised farms show a medium scheme uptake.

*Spatial and Environmental Factors*

The cost estimations revealed that spatial heterogeneity and environmental characteristics determine cost variation over regions. The higher the altitude of the farm location, the higher the average scheme costs. This implies that farms located at a higher altitude (altitude 2), negotiate more payment intensive agreements. However, these findings are not statistically significant for the weighted models which suggests that compliance behaviour might be not related to spatial heterogeneity. With respect to the Less Favoured Area (LFA) indicators we found that the more farmland is part of such an area, the higher are the average costs per ha under the conservation agreement. This is indicated by the relatively high coefficient values for ‘all land inside SDA’ and ‘all land inside DA’ across all models estimated. Farms in such areas have a high incentive to use the relatively risk free income related to such ecosystem services, hence, the probablity that such farms join the scheme and actually comply with the requirements is relatively high compared to farms outside such areas. The overlap of the ESS scheme with a Less Favoured Area could increase administrative burdens given the greater geographical remoteness and greater travel time required of administrative staff. The inclusion of a substantial area of common land in the ESS may increase administrative costs through increasing the complexity of negotiating management agreements (see also MacFarlane, 1998). In addition the random effects intercepts incorporated with respect to unobserved variation over government office regions and counties show a high statistical significance and large estimates for all cost models. This suggests that (unobservable) spatial variation in environmental characteristics of the participating farms has a significant effect on the cost-effectiveness of the instrument.

*Scope and Jointness in Schemes’ Production*

Finally we found strong empirical evidence for significant cost savings due to economies of scope with respect to other agri-environmental schemes - here: the Nitrate Vulnerable Scheme (NVZ) and the Hill Farm Allowance Scheme (HFA). The estimated coefficients for both schemes are significantly negative indicating lower average ESS scheme costs per ha for those farms also enrolled in the NVZ and/or the HFA scheme. This suggests, that there are indeed positive spillover effects from the joint implementation of, and participation of farmers in, other related agri-environmental schemes: total administration costs might increase in a non-linear way with the number of additional schemes as the costs of activities such as initial farm surveys and ecological monitoring can be shared.

However, these findings are reverse for the compliance unweighted cost models. Here strong evidence for diseconomies of scope were found. This could be evidence that on the other side administration costs may rise, given the need to coordinate schemes and prevent overlap, double payments and so on. Average costs might be expected to fall with scheme experience for both farmers and the conservation agencies in the long run (see Falconer et al 2001). Finally, the participating farmer might have an incentive to use land already under the NVZ and/or HFA scheme also for an ESS agreement, hence, the net effect in terms of area under conservation might be decreasing. These differences for the unweighted/weighted models again suggest that the consideration of a regional variance in compliance behaviour leads to additional insights with respect to scheme cost drivers.

In summary, we found empirical evidence for all hypotheses: The average scheme costs significantly vary at a regional level and over time (hypotheses 1 and 2). Scheme related characteristics show a considerable influence on the scheme's cost structure, we found diseconomies of scale with respect to administrative capacities and economies of agreements density (hypothesis 3). Regional and sectoral variation in the scheme uptake and cost of compliance for the participating farms lead to significant cost effects reflecting heterogeneity with respect to management skills and attitudes, production focus, location, technologies, economic performance and risk (hypothesis 4). Finally, the empirical analysis revealed significant economies of scope with respect to the management of other agri-environmental schemes, however, only after controlling for compliance among participating farms (hypothesis 5).

To the background of previous theoretical reasoning and empirical evidence our findings suggest the following: Earlier findings that more extensive and less environmentally degrading production systems are more likely to participate in the conservation scheme (Hynes and Garvey 2009) can not be confirmed by the findings for the ESS scheme so far. Further, our cost estimations show that still diseconomies of scale are the case for the ESS scheme, hence, the optimal number of agreements has not been reached (Falconer and Whitby 2000). Conflicting results were found with respect to economies of density/agglomeration: Considering compliance behaviour makes a difference with respect to the average scheme cost supporting the conclusions by Falconer et al (2001) that the extent of scheme participation is important in explaining administrative cost variability across space. We further found that the decisions to participate in a conservation scheme and work off the farm are correlated (Chang and Boisvert 2009). Age has an effect on the willingness to join and comply with the scheme requirements (Vanslembrouck 2002): the individual cost of compliance vary by age and experience. The significance of the agreements density proxy also reflects the effects of peer-group interaction and the importance of network externalities with respect to information gathering and compliance signalling (Brock and Durlauf 2001, Sauer and Zilberman 2009). Our results confirm theoretical reasoning on the importance of risk for the scheme participants' behaviour, scheme costs decrease as the individual compliance costs decrease as a result of increasing market and production risk (Fraser 2009). Hence, incentive-compatible scheme design has to be based on quantifiable risk measures (Peterson and Boisvert 2004, Yano and Blandford 2009, Zabel and Roe 2009). However, the general notion that higher risk aversion and higher income uncertainty automatically lead to lower costs for the conservation agency can not be confirmed per se as payment costs do increase as scheme participation is used to hedge against such risk (subject to agreements' composition).

By controlling for unobserved heterogeneity and/or path dependency with respect to farm and farmer specific factors our modelling approach reveals significant scheme cost effects by space and administrative cluster related factors (Hynes and Garvey 2009). Further, technological characteristics and economic performance related factors are essential to correctly understand and predict farms' participation and compliance behaviour (Berentsen et al 2007). Adverse selection related cost implications can be approximated by relevant performance measurement on farm level. Our analysis confirms the empirical validity of earlier suggestions of a spatially defined scheme payment mechanism reflecting the spatial heterogeneity of environmental impacts (Waetzold and Drechsler 2005, Canton et al 2009, Fraser 2009). Spatial targeting should be used by the conservation agency or regulator to reduce the cost effects of asymmetric information. This could be linked to a delegation of the scheme implementation to sub-regional authorities to significantly reduce such deficiencies. Finally, our results show that average compliance behaviour determines to a certain extent if the joint production of policy instruments can lead to cost savings through scale effects. There are indeed positive spillover effects from the joint implementation of, and participation of farmers in, other related agri-environmental schemes: total administration costs might increase in a non-linear way (Heyes 1998). Hence, there is scope for the conservation agency to exploit 'issue-linkage' (i.e. the farmer may operate several holdings, operate at different locations, or be subject to different environmental regulations).

**7 – Conclusions and Policy Implications**

This analysis contributes to the literature in the following ways: There are still only a very few empirical studies available investigating the performance of environmental schemes using microdata at the farm level. We control for the actual level of compliance per region by using compliance weighted average scheme cost ratios. Beside technological and economic performance measures, we also consider proxies for risk at farm level. Hence, we go further than existing studies on environmental schemes and aim to empirically investigate the theoretically well explored policy implications of adverse selection and moral hazard. In addition we consider unobserved heterogeneity or path dependency with respect to unknown spatial and farm specific factors. Hence, we try to disentangle random and fixed scheme cost effects by applying a robust mixed-effects estimation approach. By following a three-stage estimation procedure we significantly contribute to the literature by improving on earlier empirical studies. We simultaneously model fixed and (unobservable) random scheme cost effects by avoiding inconsistencies implied by other estimators. To avoid small sample bias and non-robust results we use a satisfactorily large sample for the full ESS scheme and a statistical resampling procedure. The results reveal that the average scheme costs significantly vary at a regional level and over time. Scheme related characteristics show a considerable influence on the scheme's cost structure, we found diseconomies of scale with respect to administrative capacities and economies of density with respect to the number of agreements. Regional and sectoral variation in the scheme uptake and cost of compliance for the participating farms lead to significant cost effects reflecting heterogeneity with respect to management skills and attitudes, production focus, location, technologies, economic performance and risk. Finally, by controlling for compliance among participating farms the empirical analysis suggests significant economies of scope with respect to the joint production and management of different agri-environmental schemes.

However, existing constraints upon the administrative budget setting process mean that administrative inputs are unlikely to be optimal at any given time, hence, the empirical results must be interpreted with caution. The inflexibility in administrative structures must also be considered: e.g. planned staffing adjustments are likely to be made only on a pre-fixed time basis. Input quality variations must be taken into account when evaluating administrative performance which are not ncessarily reflected in the costs (e.g. in wage costs). Nevertheless, despite the empirical findings are subject to accurate data availability they have essential utility in providing valuable benchmark figures for further scheme revisions towards an increased instrument efficiency.

Finally, the following essential policy implications should be outlined:

(1) Diseconomies of scale are the case for the ESS scheme, hence, the optimal number of agreements has not been reached yet.
(2) The consideration of compliance behaviour makes a difference with respect to the average scheme cost supporting the view that the extent of scheme participation is important in explaining variability in administrative cost-effectiveness across space and sectors.
(3) The decisions to participate in a conservation scheme and work off the farm are correlated, hence, agri-environmental schemes can serve as vehicle for other policy aims.
(4) The individual cost of compliance vary by age and experience of the scheme participant which points to the importance of scheme marketing and information dissemination.
(5) The significance of the agreements' density also reflects the effects of peer-group interaction and the importance of network externalities with respect to information gathering and compliance signalling.
(6) Incentive-compatible scheme design has to be based on quantifiable risk measures.

(7) Informed (and quantified) analysis about recipients technological characteristics and economic performance is crucial for the instrument's success. Economic performance and compliance is linked.
(8) Spatial (sub-regional) targeting of scheme payment mechanisms is crucial to reflect the spatial heterogeneity of environmental impacts.
(9) The average compliance behaviour determines to a certain extent if the joint production of policy instruments can lead to cost savings through scale effects.
(10) There is considerable scope for the conservation agency to exploit 'issue-linkage' with respect to cost savings (i.e. the farmer may operate several holdings, operate at different locations, or be subject to different environmental regulations and participates in different schemes).

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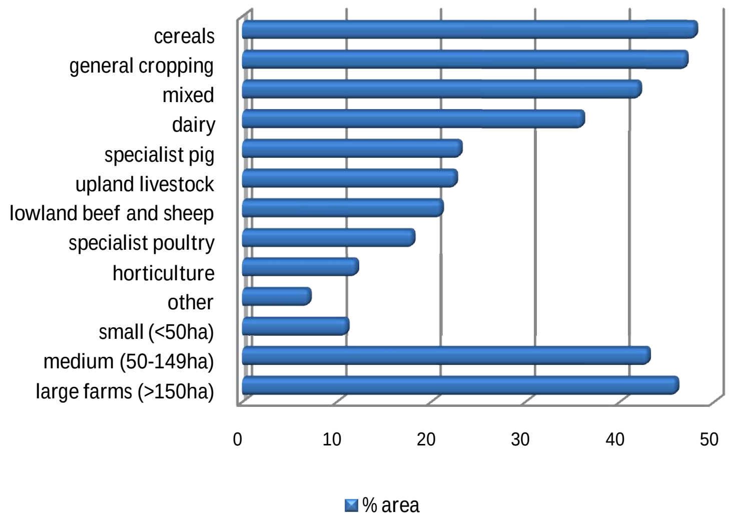
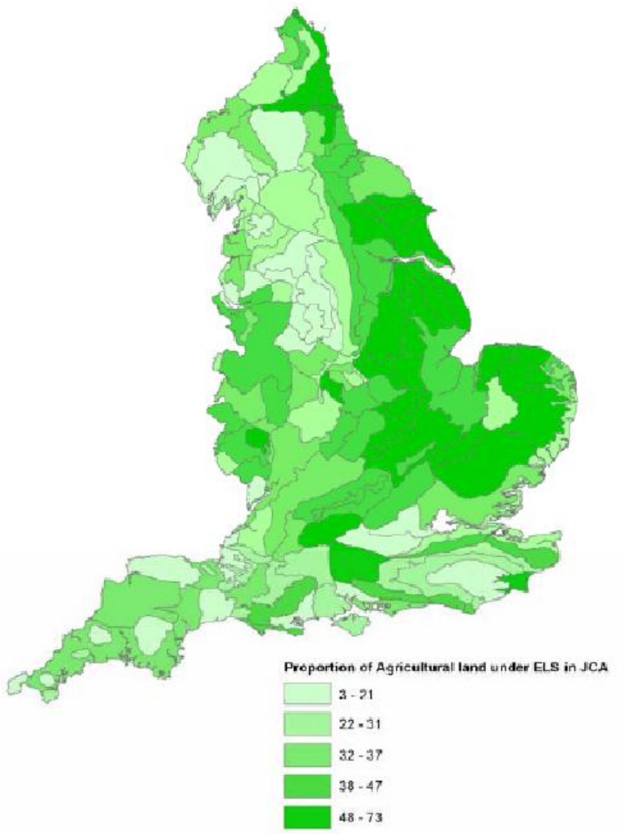
## Appendix

Figure A1 – Sectoral Variation in ELS Uptake (by FBS Farm Specification 2008)




(Based on FBS 2008 data, FBS: Farm Business Survey)

Map A1 – Geographical Variation in ELS Uptake (by JCA)




(Based on Chaplin 2009 and Farm Business Survey 2008, JCA: Joint Classification Area)

Table A1 – Bootstrapped Descriptive Statistics for Scheme Cost-Ratios at GOR level (2006 to 2008)

| Cost-Ratio *(GBP per ha and year)* | Mean | Standard Deviation | Minimum | Maximum | Bias Standard Error | 95% Confidence Interval for Mean (Bias Corrected) | |
|---|---|---|---|---|---|---|---|
| Cost Ratio 1 | 96.411 | 39.291 | 14.457 | 159.414 | 0.012 | 81.533 | 110.847 |
| Cost Ratio 1c | 138.358 | 85.222 | 14.764 | 410.835 | -0.052 | 110.214 | 174.463 |
| Cost Ratio 2 | 99.484 | 42.119 | 32.056 | 196.424 | 0.111 | 84.175 | 115.853 |
| Cost Ratio 2c | 143.931 | 97.393 | 33.837 | 476.837 | -0.051 | 112.532 | 186.318 |
| Cost Ratio 3 | 98.931 | 40.838 | 31.493 | 185.147 | -0.023 | 84.192 | 114.813 |
| Cost Ratio 3c | 143.332 | 96.787 | 33.243 | 475.512 | 0.286 | 111.602 | 182.950 |
| Cost Ratio 4 | 97.174 | 39.077 | 25.912 | 174.816 | 0.022 | 82.961 | 111.682 |
| Cost Ratio 4c | 140.413 | 93.706 | 27.351 | 470.475 | -0.039 | 110.609 | 180.783 |

(GOR – government office region; 27 observations; 10,000 Bootstrap Replications; c – compliance weighted; All financial variables have been deflated to the base year 2006 using inflation rate published by National Statistics UK. The underlying cost data per region can be obtained from the author upon request.)

Table A2 – Descriptive Statistics for Farms Participating in the ESS Scheme (2006 to 2008)

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| total output (GBP) | 284252.6 | 426218 | 8177 | 9194788 |
| primary output (GBP; more than 50% of total agricultural output) | 187033.1 | 322753.6 | 275 | 7090607 |
| secondary output (GBP) | 97219.53 | 141102.8 | 1 | 2170542 |
| land (ha) | 196.364 | 222.298 | 7.28 | 2587.23 |
| labor (hours) | 5532.233 | 8858.383 | 36 | 231925 |
| fodder (GBP) | 1673.098 | 5034.601 | 1 | 96098 |
| veterinary and medical expenses (GBP) | 3744.154 | 5748.532 | 1 | 67859 |
| seed (GBP) | 8482.003 | 34955.35 | 1 | 1086259 |
| fertilizer (GBP) | 13877.77 | 22433.84 | 1 | 356503 |
| crop protection (GBP) | 12367.77 | 28382.85 | 1 | 330271 |
| capital (GBP) | 58020.48 | 102800.2 | 1 | 2407886 |
| livestock units (n) | 120.553 | 136.1422 | 0.21 | 2482 |
| FBS robust type ‘cereals’ | 0.252 | 0.434 | 0 | 1 |
| FBS robust type ‘general cropping’ | 0.122 | 0.327 | 0 | 1 |
| FBS robust type ‘horticulture’ | 0.014 | 0.118 | 0 | 1 |
| FBS robust type ‘pigs’ | 0.008 | 0.092 | 0 | 1 |
| FBS robust type ‘poultry’ | 0.006 | 0.074 | 0 | 1 |
| FBS robust type ‘dairy’ | 0.153 | 0.361 | 0 | 1 |
| FBS robust type ‘lfa grazing livestock’ | 0.192 | 0.394 | 0 | 1 |
| FBS robust type ‘lowland grazing livestock’ | 0.128 | 0.334 | 0 | 1 |
| FBS robust type ‘mixed’ | 0.120 | 0.334 | 0 | 1 |
| FBS robust type ‘other’ | 0.004 | 0.065 | 0 | 1 |
| degree of specialisation (primary outout/total output) | 0.606 | 0.189 | 0.006 | 1 |
| off-farm income (GBP) | 10001.81 | 17244.68 | 0 | 301750 |
| debt to assets ratio | 0.149 | 0.247 | 2.40e-06 | 8.847 |
| profit (loss) per ha (GBP) | 1929.557 | 4204.859 | -133.891 | 80475.13 |
| area under NVZ scheme (ha) | 45.207 | 49.501 | 0 | 328 |
| payments received from HFA scheme (GBP) | 778.877 | 1888.806 | 0 | 16557 |
| altitude ‘below 300m’ (0 or 1) | 0.886 | 0.318 | 0 | 1 |
| altitude ‘300m to 600m’ (0 or 1) | 0.106 | 0.308 | 0 | 1 |
| altitude ‘600m or over’ (0 or 1) | 0.008 | 0.090 | 0 | 1 |
| LFA: ‘all land outside lfa’ (0 or 1) | 0.731 | 0.443 | 0 | 1 |
| LFA: ‘all land inside sda’ (0 or 1) | 0.093 | 0.290 | 0 | 1 |
| LFA: ‘all land inside da’ (0 or 1) | 0.043 | 0.204 | 0 | 1 |
| LFA: ‘50%+ in lfa of which 50%+ in sda’ (0 or 1) | 0.063 | 0.244 | 0 | 1 |
| LFA: ‘50%+ in lfa of which 50%+ in da’ (0 or 1) | 0.041 | 0.198 | 0 | 1 |
| LFA: ‘<50% in lfa of which 50%+ in sda’ (0 or 1) | 0.007 | 0.087 | 0 | 1 |
| LFA: ‘<50% in lfa of which 50%+ in da’ (0 or 1) | 0.021 | 0.142 | 0 | 1 |
| age (years) | 53.703 | 10.525 | 22 | 90 |
| gender (0-male, 1-female) | 0.025 | 0.156 | 0 | 1 |
| year 2006 (0 or 1) | 0.252 | 0.434 | 0 | 1 |
| year 2007 (0 or 1) | 0.330 | 0.470 | 0 | 1 |
| year 2008 (0 or 1) | 0.418 | 0.493 | 0 | 1 |

(2286 observations; financial variables deflated to base year 2006; FBS – farm business survey, NVZ – nitrate vulnerable scheme, HFA – hill farm allowance, LFA – less favoured area, SDA – severely disadvanteged area, DA – disadvantaged area)

Table A3 – Other ESS Scheme Characteristics on GOR level (2006 to 2008)

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| number of els/ols agreements per region and year | 833.667 | 726.372 | 2 | 3133 |
| number of hls agreements per region and year | 112.222 | 68.201 | 1 | 282 |
| number of ess agreements live per region and year | 868.407 | 710.431 | 3 | 3083 |
| total area under els/ols agreement per region and year (ha) | 120435.2 | 98449.31 | 270.43 | 402445 |
| total area under hls agreement per region and year (ha) | 11479.43 | 7081.836 | 42.04 | 23234.82 |
| total area under ess agreement per region and year (ha) | 945.889 | 783.833 | 3 | 3415 |
| density of ess agreements per region and year (ess agreements per region and year / total ess agreements per year, 0 to 1) | 0.037 | 0.031 | 1.17e-04 | 0.134 |

(27 observations; 'live agreements' – including also initiated agreement negotiations; 'els'- entry level scheme, 'ols' - organic level scheme, 'hls' - higher level scheme)

Table A4 – Technological Variables and Risk Proxies for Farm Sample (2006 to 2008)

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| technical efficiency | 0.463 | 0.217 | 0.106 | 1 |
| farm size (FBS size bands 1 to 3) | 2.154 | 0.820 | 1 | 3 |
| scale inefficiency | 0.179 | 0.335 | 0.132 | 0.978 |
| risk proxy 1 – expected profit (mean) | -9.46e-10 | 0.681 | -3.215 | 2.586 |
| risk proxy 2 – profit variability (variance) | 0.465 | 0.275 | -0.370 | 4.539 |
| risk proxy 3 – profit asymmetry (skewness) | -0.012 | 0.406 | -12.214 | 1.533 |
| risk proxy 4 – profit peakedness (kurtosis) | 0.808 | 1.539 | -2.986 | 47.219 |
| risk proxy 5 – effect on expected profit*time | -2.88e-09 | -1.584 | -9.647 | 7.323 |
| risk proxy 6 – variability of effect on expected profit*time | 1.017 | 0.757 | -0.370 | 13.619 |
| risk proxy 7 – asymmetry of effect on expected profit*time | -0.043 | 1.017 | -36.642 | 4.088 |
| risk proxy 8 – peakedness of effect on expected profit*time | 1.809 | 3.963 | -5.941 | 141.659 |

(2286 observations)

Table A5 – Bootstrapped Summary Statistics for Scheme Cost-Ratios in Different Years

| Cost-Ratio *(GBP per ha)* | Mean | Standard Deviation | Minimum | Maximum | Bias Standard Error | 95% Confidence Interval for Mean (Bias Corrected) | |
|---|---|---|---|---|---|---|---|
| Cost Ratio 1 2006 | 65.235 | 22.578 | 17.153 | 95.688 | -2.088 | 49.605 | 77.588 |
| Cost Ratio 2 2006 | 64.615 | 18.026 | 32.055 | 90.529 | -1.425 | 53.328 | 75.285 |
| Cost Ratio 3 2006 | 64.399 | 17.907 | 31.493 | 90.661 | -1.477 | 52.696 | 75.253 |
| Cost Ratio 4 2006 | 66.696 | 22.912 | 25.911 | 104.473 | -1.933 | 52.924 | 80.315 |
| Cost Ratio 1 2007 | 98.541 | 40.576 | 14.456 | 156.915 | -3.696 | 71.237 | 121.488 |
| Cost Ratio 2 2007 | 106.104 | 43.563 | 49.507 | 196.424 | -4.045 | 82.275 | 136.071 |
| Cost Ratio 3 2007 | 104.900 | 40.252 | 50.118 | 185.147 | -3.537 | 82.329 | 133.198 |
| Cost Ratio 4 2007 | 100.362 | 35.863 | 33.216 | 150.465 | -3.064 | 77.355 | 121.225 |
| Cost Ratio 1 2008 | 125.454 | 28.521 | 82.841 | 159.413 | -1.971 | 107.284 | 142.257 |
| Cost Ratio 2 2008 | 127.732 | 35.041 | 69.390 | 175.937 | -2.694 | 106.534 | 149.333 |
| Cost Ratio 3 2008 | 127.493 | 34.348 | 69.505 | 175.082 | -2.561 | 106.568 | 149.060 |
| Cost Ratio 4 2008 | 124.465 | 35.456 | 69.491 | 174.816 | -2.698 | 102.919 | 146.183 |
| Cost Ratio 1c 2006 | 76.976 | 30.671 | 18.106 | 124.491 | -2.630 | 57.206 | 95.473 |
| Cost Ratio 2c 2006 | 76.650 | 28.900 | 33.836 | 128.367 | -2.344 | 60.094 | 95.347 |
| Cost Ratio 3c 2006 | 76.466 | 29.100 | 33.242 | 129.183 | -2.425 | 59.704 | 95.838 |
| Cost Ratio 4c 2006 | 78.854 | 32.051 | 27.351 | 132.600 | -2.552 | 59.816 | 98.553 |
| Cost Ratio 1c 2007 | 127.532 | 66.540 | 14.764 | 244.208 | -5.787 | 88.601 | 171.847 |
| Cost Ratio 2c 2007 | 138.913 | 81.799 | 50.560 | 317.128 | -8.217 | 97.228 | 197.554 |
| Cost Ratio 3c 2007 | 137.537 | 80.006 | 51.185 | 315.475 | -8.431 | 96.780 | 195.551 |
| Cost Ratio 4c 2007 | 131.386 | 72.502 | 33.923 | 288.315 | -7.649 | 94.066 | 183.404 |
| Cost Ratio 1c 2008 | 210.565 | 89.439 | 123.092 | 410.835 | -9.809 | 165.481 | 278.180 |
| Cost Ratio 2c 2008 | 216.231 | 110.904 | 122.479 | 476.837 | -14.099 | 164.107 | 301.030 |
| Cost Ratio 3c 2008 | 215.994 | 110.409 | 123.535 | 475.512 | -13.989 | 162.635 | 300.728 |
| Cost Ratio 4c 2008 | 210.999 | 110.878 | 120.141 | 470.474 | -14.258 | 157.348 | 297.663 |

(9 observations per year; 10,000 Bootstrap Replications; c – compliance weighted; Due to confidentialty reasons we are not able to show the variation of the cost ratios at regional – i.w. GOR - level. The underlying cost data per region can be obtained from the author upon request.)

A6 - Cost Ratios Calculations

*cost ratio* $1_{gt}$ = [total costs for administration, monitoring and evaluation$_t$*
(payments for region g / Σ payments all regions G)$_t$ + total costs for inspection at regional level$_t$
+ payments for all ESS options at regional level$_t$] / (total area under all ESS options for region g)$_t$

(A1)

*cost ratio* $2_{gt}$ = [total costs for administration, monitoring and evaluation$_t$*
(number of current agreements for region g / Σ number of current agreements for all regions G)$_t$
+ total costs for inspection at regional level$_t$ + payments for all ESS options at regional level$_t$]
/ (total area under all ESS options for region g)$_t$

(A2)

*cost ratio* $3_{gt}$ = [total costs for administration, monitoring and evaluation$_t$*
(total number of agreements for region g / Σ total number of agreements for all regions G)$_t$
+ total costs for inspection at regional level$_t$ + payments for all ESS options at regional level$_t$]
/ (total area under all ESS options for region g)$_t$

(A3)

*cost ratio* $4_{gt}$ =
Σ (cost ratio $1_{gt}$, $2_{gt}$ and $3_{gt}$) / 3

(A4)

*cost ratio* $1C_{gt}$ = cost ratio $1_{gt}$ / (compliance rate for region g)$_t$

(A5)

*cost ratio* $2C_{gt}$ = cost ratio $2_{gt}$ / (compliance rate for region g)$_t$

(A6)

*cost ratio* $3C_{gt}$ = cost ratio $3_{gt}$ / (compliance rate for region g)$_t$
proxy for compliance rate$_{gt}$ = 1 - (monitoring visits where initial findings were unsatisfactory / all monitoring visits)$_{gt}$

(A7)

*cost ratio* $4C_{gt}$ = Σ (cost ratio $1C_{gt}$, $2C_{gt}$ and $3C_{gt}$) / 3

(A8)

(where t = 2006, 2007, 2008)

Table A6 Estimates Bootstrapped Mixed-Effects REML Regressions – Unweighted Cost Ratios

| *Dependent Variable* | Model 1<br>Cost Ratio 4 | | Model 2<br>CR 1 | | Model 3<br>CR 2 | | Model 4<br>CR 3 | |
|---|---|---|---|---|---|---|---|---|
| *Independent Variables (Fixed Effects)* | *est* | *se* [5] | *est* | *se* | *est* | *se* | *est* | *se* |
| Total ESS Agreements | .124*** | .002 | .055*** | .002 | .352*** | .005 | .329*** | .004 |
| Total ESS Agreements (squared) | -6.93e-05*** | 1.01e-06 | -3.15e-05*** | 1.27e-06 | -1.43e-04*** | 2.34e-06 | -1.37e-04*** | 2.08e-06 |
| Density of ESS Farms on GOR level | 61.568*** | 1.194 | 37.591*** | 1.544 | 70.016*** | 2.802 | 71.511*** | 2.484 |
| Year 2007 | 24.873*** | .455 | 31.077*** | .503 | 79.059*** | 1.071 | 71.444*** | .945 |
| Year 2008 | 55.9769** | .701 | 56.208*** | .910 | 144.207*** | 1.644 | 133.872*** | 1.321 |
| Age | -.012*** | .004 | -.019*** | .006 | -.033*** | .010 | -.029*** | .009 |
| Gender | -.260 | .278 | -.309 | .362 | -.569 | .656 | -.508 | .581 |
| Robust Type 1 ‘cereals’ | .015*** | .004 | .271** | 0.101 | .579*** | 0.089 | .444*** | 0.073 |
| Robust Type 2 ‘general cropping’ | .334 | .853 | .222 | 1.111 | -.316 | 2.011 | .304 | 1.782 |
| Robust Type 3 ‘horticulture’ | .134 | .904 | .415 | 1.178 | .873 | 2.131 | .748 | 1.888 |
| Robust Type 4 ‘pigs’ | 2.391*** | .950 | 2.609** | 1.237 | 3.556* | 2.002 | 3.193*** | 1.984 |
| Robust Type 5 ‘poultry’ | .233 | .998 | .544 | 1.300 | 1.119 | 2.352 | .967 | 2.084 |
| Robust Type 6 ‘dairy’ | .212 | .856 | .404 | 1.116 | .914 | 2.019 | .793 | 1.789 |
| Robust Type 7 ‘lfa grazing livestock’ | -.088*** | .009 | -.051*** | 0.001 | -.119*** | 0.029 | -.060*** | 0.019 |
| Robust Type 8 ‘lowland grazing livestock’ | -.218*** | .084 | -.127 | 1.100 | -.106** | 0.019 | -.114 | 1.764 |
| Robust Type 9 ‘mixed’ | .341 | .852 | .676 | 1.110 | 1.385 | 2.009 | 1.202 | 1.780 |
| Output Elasticity wrt Secondary Output [1] | .135* | .083 | .189** | .101 | .390** | .143 | .317** | .173 |
| Output Elasticity wrt Land Input [1] | .251 | .179 | .356* | .233 | .728* | .422 | .647* | .374 |

1 : Estimates obtained by Generalized Transformation Frontier; 2 : Estimates obtained by Translog Profit Function; *,**,*** : Significance at 10%- , 5%- , or 1%-Level; 5: Bootstrapped SE

*Table A6 cont.*

| *Dependent Variable* | Cost Ratio 4 | | CR 1 | | CR 2 | | CR 3 | |
|---|---|---|---|---|---|---|---|---|
| *Independent Variables (Fixed Effects)* | *est* | *se* [5] | *est* | *se* | *est* | *se* | *est* | *se* |
| Output Elasticity wrt Labor Input [1] | .031 | .046 | .058 | .061 | .109 | .110 | .094 | .098 |
| Output Elasticity wrt Fodder Input [1] | -.472*** | .056 | -.249*** | .073 | -.759 | 1.326 | -.736 | 1.175 |
| Output Elasticity wrt Veterinary/Medical Input [1] | -.132*** | .056 | -.175*** | .072 | -.345*** | .131 | -.306*** | .117 |
| Output Elasticity wrt Seed Input [1] | .075 | .259 | .126 | .338 | .288 | .611 | .254 | .542 |
| Output Elasticity wrt Fertilizer Input [1] | .045 | .110 | .104 | .143 | .209 | .259 | .182 | .229 |
| Output Elasticity wrt Crop Protection Input [1] | .573*** | .059 | .282 | .773 | .823*** | 0.139 | .809 | 1.239 |
| Output Elasticity wrt Capital Input [1] | .002 | .077 | .041 | .100 | .066 | .181 | .052 | .161 |
| Output Elasticity wrt Livestock Input [1] | -.295 | .290 | -.293 | .378 | -.545 | .684 | -.498 | .606 |
| Technical Change [1] | .021** | .009 | .029** | .129 | .075*** | .023 | .067*** | .021 |
| Technical Efficiency [1] | .347*** | .025 | .503 | .345 | .926*** | .069 | .816 | .553 |
| Farm Size | .013 | .075 | .004 | .098 | .002 | .178 | .003 | .158 |
| Scale Efficiency [1] | -.012*** | .003 | -.032** | .017 | .035 | .301 | -.030 | .267 |
| Degree of Specialisation | .069 | .251 | .212 | .327 | .551 | .593 | .469 | .525 |
| Profit per Hectar | -2.31e-04** | 1.06e-05 | -2.75e-05** | 1.33e-05 | -4.99e-05** | 2.49e-05 | -4.43e-05** | 2.11e-05 |
| Off-Farm Income | -5.40e-06** | 2.52e-06 | -6.74e-06** | 3.28e-06 | -1.11e-05** | 5.04e-06 | -9.88e-06** | 5.06e-06 |
| Debt to Assets | .376** | .170 | .602*** | .222 | 1.05*** | .402 | .922*** | .356 |
| Area under Nitrate Vulnerable Scheme | .005*** | .001 | .006*** | .001 | .011*** | .003 | .009*** | .002 |
| Income due to Hill Farm Allowance Scheme | 1.11e-04*** | 2.74e-05 | 1.71e-04*** | 3.55e-05 | 3.10e-04*** | 6.46e-05 | 2.73e-04*** | 5.71e-05 |

1 : Estimates obtained by Generalized Transformation Frontier; *,**,*** : Significance at 10%- , 5%- , or 1%-Level; 5: Bootstrapped SE

*Table A6 cont.*

| *Dependent Variable* | Cost Ratio 4 | | CR 1 | | CR 2 | | CR 3 | |
|---|---|---|---|---|---|---|---|---|
| *Independent Variables (Fixed Effects)* | *est* | *se* [5] | *est* | *se* | *est* | *se* | *est* | *se* |
| Risk Proxy 1 – Expected Profit (Mean) [2] | -.496*** | .196 | -.627*** | .255 | -.991** | .463 | -.885** | .410 |
| Risk Proxy 2 – Profit Variability (Variance) [2] | 1.351*** | 0.101 | 1.470*** | 0.301 | -2.839 | 2.367 | 2.581** | 1.053 |
| Risk Proxy 3 – Profit Asymmetry (Skewness) [2] | -.383*** | .053 | -.131** | .032 | .426 | 1.311 | -.332** | 0.153 |
| Risk Proxy 4 – Profit Peakedness (Kurtosis) [2] | .002 | .241 | .134*** | .034 | .279 | .594 | .243 | .527 |
| Risk Proxy 5 – Expected Profit * Time [2] | -.197*** | .080 | -.243*** | .104 | -.387** | .189 | -.346** | .167 |
| Risk Proxy 6 – Variability of Profit * Time [2] | .897** | .419 | 1.053** | .545 | 2.014** | .987 | 1.814** | .875 |
| Risk Proxy 7 – Asymmetry of Profit * Time [2] | -.117*** | .023 | -.414*** | .031 | -.786*** | .055 | -.680 | .491 |
| Risk Proxy 8 – Peakedness of Profit * Time [2] | .109 | .103 | .197* | .134 | .388* | .204 | .325* | .201 |
| Altitude 1 – Most of Holding at 300m-600m [3] | -.404*** | .233 | -.505** | .304 | -.964* | .549 | -.849* | .487 |
| Altitude 2 – Most of Holding at >600m [3] | .544 | .580 | .838 | .753 | 1.331 | 1.365 | 1.169 | 1.210 |
| Less Favoured Area 1 – All Land inside SDA [4] | .183*** | .036 | .208*** | .046 | .487*** | .084 | .455 | .741 |
| Less Favoured Area 2 – All Land inside DA [4] | .233 | .346 | .212 | .449 | .431 | .814 | .386 | .721 |
| Less Favoured Area 3 – 50%+ Land in LFA of which 50%+ in SDA [4] | .191*** | .034 | .185*** | .044 | .239 | .797 | .192*** | .006 |
| Less Favoured Area 4 – 50%+ Land in LFA of which 50%+ in DA [4] | .149 | .365 | .074 | .475 | .405 | .860 | .413 | .762 |
| Less Favoured Area 5 – <50% Land in LFA of which 50%+ in SDA [4] | -.098 | .575 | -.081 | .750 | -.114 | 1.356 | -.101 | 1.202 |
| Less Favoured Area 6 – <50% Land in LFA of which 50%+ in DA [4] | .205 | .335 | .297 | .436 | .653 | .789 | .571 | .699 |
| Constant | 29.023** | 13.737 | 47.928*** | 10.859 | -116.441*** | 30.172 | -100.596*** | 27.418 |

2 : Estimates obtained by Translog Profit Function; 3 : Reference Category ‘Most of Holding <300m’; 4 : Reference Category ‘All Land Outside LFA’; *,**,*** : Significance at 10%- , 5%- , or 1%-Level;
5: Bootstrapped SE

*Table A6 cont.*

| *Dependent Variable* | Cost Ratio 4 | | CR 1 | | CR 2 | | CR 3 | |
|---|---|---|---|---|---|---|---|---|
| *Random Effects Parameters* | *est* | *se* [5] | *est* | *se* | *est* | *se* | *est* | *se* |
| Government Office Region (n = 8) [5] | | | | | | | | |
| Standard Deviation (Constant) | 38.561*** | 10.237 | 31.124*** | 8.001 | 85.787*** | 21.382 | 76.922*** | 21.111 |
| County (n = 65) [5] | | | | | | | | |
| Standard Deviation (Constant) | 4.443*** | .822 | 3.892*** | .665 | 6.766*** | .994 | 7.778*** | .881 |
| Time (n = 607) [5] | | | | | | | | |
| Standard Deviation (Constant) | 59.650** | 22.362 | 71.051*** | 26.588 | 86.454** | 43.312 | 119.807** | 59.992 |
| Standard Deviation (Residual) | 2.124*** | .030 | 2.767*** | .039 | 5.006*** | .072 | 4.435*** | .064 |
| Likelihood-Ratio Test / Chi2(3) ($H_0$ : Non-Linear Functional Form) | 11775.12 / 0.000 | | 9318.02 / 0.000 | | 8218.18 / 0.000 | | 8533.10 / 0.000 | |
| Log-Restricted Likelihood | -5766.393 | | -6386.659 | | -7872.1498 | | -7574.3544 | |
| Wald Chi2(52) / Prob > Chi2 | 26937.83 / 0.000 | | 20522.06 / 0.000 | | 15043.16 / 0.000 | | 16826.36 / 0.000 | |
| Bootstrap Replications | 1000 | | 1000 | | 1000 | | 1000 | |
| Number of Observations | 2286 | | 2286 | | 2286 | | 2286 | |

5 : Single-Variable Random-Effects Specification; Covariance Structure set to Identity; *,**,*** : Significance at 10%- , 5%- , or 1%-Level; 5: Bootstrapped SE

Table A7 Estimates Bootstrapped Mixed-Effects REML Regressions –Cost Ratios Weighted By Compliance

| *Dependent Variable* | Model 5 Cost Ratio 4C | | Model 6 CR 1C | | Model 7 CR 2C | | Model 8 CR 3C | |
|---|---|---|---|---|---|---|---|---|
| *Independent Variables (Fixed Effects)* | *est* | *se* [5] | *est* | *se* | *est* | *se* | *est* | *se* |
| Total ESS Agreements | .121*** | 0.006 | .021*** | .005 | .363*** | .006 | .341*** | .005 |
| Total ESS Agreements (squared) | -8.45e-05*** | 3.09e-06 | -1.61e-05*** | 2.76e-06 | -1.66e-04*** | 2.84e-06 | -1.59e-04*** | 2.82e-06 |
| Density of ESS Farms on GOR level | -58.669*** | 3.576 | -135.474*** | 3.201 | -45.507*** | 3.285 | -44.015*** | 3.259 |
| Year 2007 | 71.123*** | 1.122 | 94.665*** | 1.113 | 125.503*** | 1.161 | 117.333*** | 1.112 |
| Year 2008 | 129.231*** | 2.004 | 149.323*** | 1.763 | 222.292*** | 1.832 | 211.237*** | 1.788 |
| Age | .025** | .012 | .028** | .011 | .006*** | .001 | .011 | .011 |
| Gender | -.243 | .830 | -.077 | .743 | -.530 | .763 | -.468 | .757 |
| Robust Type 1 ‘cereals’ | 2.560*** | 0.548 | 2.319** | 1.252 | 1.924*** | 0.713 | 2.023*** | 0.294 |
| Robust Type 2 ‘general cropping’ | 2.027 | 2.545 | 1.731 | 2.279 | -1.943 | 2.337 | 1.935 | 2.319 |
| Robust Type 3 ‘horticulture’ | 2.696 | 2.697 | 2.561 | 2.415 | 1.892 | 2.477 | 2.033 | 2.457 |
| Robust Type 4 ‘pigs’ | 4.339* | 2.803 | 3.615* | 2.012 | 5.178** | 2.601 | 4.918** | 2.585 |
| Robust Type 5 ‘poultry’ | 2.531 | 2.977 | 2.491 | 2.665 | 1.627 | 2.734 | 1.786 | 2.712 |
| Robust Type 6 ‘dairy’ | 1.475 | 2.556 | 1.602 | 2.288 | .714 | 2.347 | .848 | 2.329 |
| Robust Type 7 ‘lfa grazing livestock’ | -1.485*** | 0.264 | -1.110*** | 0.237 | -1.293*** | 0.243 | -1.354*** | 0.241 |
| Robust Type 8 ‘lowland grazing livestock’ | -1.512*** | 0.252 | -1.357*** | 0.226 | -1.347 | 2.314 | -1.360 | 2.296 |
| Robust Type 9 ‘mixed’ | 2.543 | 2.543 | 2.569 | 2.277 | -1.476 | 2.336 | 1.670 | 2.317 |
| Output Elasticity wrt Secondary Output [1] | .071** | .022 | .159 | .220 | .152** | .064 | .092** | .025 |
| Output Elasticity wrt Land Input [1] | .409*** | .053 | .591*** | .048 | .075* | .049 | .014 | .487 |

1 : Estimates obtained by Generalized Transformation Frontier; 2 : Estimates obtained by Translog Profit Function; *,**,*** : Significance at 10%- , 5%- , or 1%-Level; 5: Bootstrapped SE

*Table A7 cont.*

| *Dependent Variable* | Cost Ratio 4C | | CR 1C | | CR 2C | | CR 3C | |
|---|---|---|---|---|---|---|---|---|
| *Independent Variables (Fixed Effects)* | *est* | *se* [5] | *est* | *se* | *est* | *se* | *est* | *se* |
| Output Elasticity wrt Labor Input [1] | .196 | .139 | .182 | .125 | .124 | .128 | .139 | .127 |
| Output Elasticity wrt Fodder Input [1] | -3.220** | 1.679 | -1.974 | 1.504 | -3.691*** | 1.540 | -3.642*** | 1.530 |
| Output Elasticity wrt Veterinary/Medical Input [1] | -.084*** | .017 | -.181*** | .014 | -.132 | .153 | -.091 | .152 |
| Output Elasticity wrt Seed Input [1] | .294 | .774 | .375 | .693 | .081 | .711 | .116 | .705 |
| Output Elasticity wrt Fertilizer Input [1] | .472*** | .028 | .467* | .290 | .308 | .301 | .336 | .299 |
| Output Elasticity wrt Crop Protection Input [1] | 4.176*** | 1.702 | 2.699** | 1.508 | 4.633*** | 1.627 | 4.589*** | 1.614 |
| Output Elasticity wrt Capital Input [1] | .369* | .220 | .285 | .205 | .309* | .201 | .329* | .201 |
| Output Elasticity wrt Livestock Input [1] | -.777 | .867 | -.461 | .776 | -1.056 | .796 | -1.001 | .791 |
| Technical Change [1] | -.010*** | .002 | -.059** | .028 | .051 | .272 | .042 | .270 |
| Technical Efficiency [1] | -.695*** | .078 | -.761*** | .078 | -.164 | .732 | -.272 | .721 |
| Farm Size | .120 | .226 | .112 | .202 | .105 | .208 | .106 | .206 |
| Scale Efficiency [1] | -.104*** | .038 | -.073** | .034 | .099 | .351 | .101 | .348 |
| Degree of Specialisation | 1.129 | .750 | 1.190* | .670 | .635 | .690 | .718 | .684 |
| Profit per Hectar | -1.90e-05 | 3.18e-05 | -6.27e-06 | 2.87e-05 | -4.41e-05* | 2.91e-05 | -3.83e-05 | 2.87e-05 |
| Off-Farm Income | -4.71e-06*** | 7.53e-07 | 2.04e-06 | 6.74e-06 | -9.95e-06* | 5.92e-06 | 8.75e-06 | 6.86e-06 |
| Debt to Assets | 1.145** | .509 | 1.139*** | .456 | .527 | .467 | .654 | .464 |
| Area under Nitrate Vulnerable Scheme | -.009*** | .003 | -.009*** | .002 | -.002 | .003 | -.003* | .002 |
| Income due to Hill Farm Allowance Scheme | -2.93e-04*** | 8.19e-05 | -3.09e-04*** | 7.33e-05 | -9.94e-05*** | 5.52e-06 | -1.39e-04** | 7.46e-05 |

1 : Estimates obtained by Generalized Transformation Frontier; *,**,*** : Significance at 10%- , 5%- , or 1%-Level; 5: Bootstrapped SE

*Table A7 cont.*

| *Dependent Variable* | Cost Ratio 4C | | CR 1C | | CR 2C | | CR 3C | |
|---|---|---|---|---|---|---|---|---|
| *Independent Variables (Fixed Effects)* | *est* | *se* [5] | *est* | *se* | *est* | *se* | *est* | *se* |
| Risk Proxy 1 – Expected Profit (Mean) [2] | -.039*** | .006 | -.078* | .052 | -.508*** | .054 | -.398 | .534 |
| Risk Proxy 2 – Profit Variability (Variance) [2] | -1.604* | 0.998 | -.173** | 0.084 | -3.228** | 1.753 | -2.957 | 2.731 |
| Risk Proxy 3 – Profit Asymmetry (Skewness) [2] | -6.832*** | 1.540 | -6.221*** | 1.327 | -5.341*** | 1.323 | -5.913*** | 1.434 |
| Risk Proxy 4 – Profit Peakedness (Kurtosis) [2] | 1.489** | .752 | 1.428** | .674 | 1.159* | .691 | 1.222** | .605 |
| Risk Proxy 5 – Expected Profit * Time [2] | -.071 | .239 | -.013 | .214 | -.251 | .220 | -.208 | .218 |
| Risk Proxy 6 – Variability of Profit * Time [2] | .574** | 0.251 | .187 | 1.119 | 1.726* | 1.004 | 1.511 | 1.139 |
| Risk Proxy 7 – Asymmetry of Profit * Time [2] | -2.705*** | .702 | -2.561*** | .629 | -2.007*** | .645 | -2.117*** | .640 |
| Risk Proxy 8 – Peakedness of Profit * Time [2] | -.608** | .308 | -.637*** | .270 | -.338 | .283 | -.389* | .200 |
| Altitude 1 – Most of Holding at 300m-600m [3] | -.103 | .695 | .129 | .622 | -.648 | .638 | -.528 | .630 |
| Altitude 2 – Most of Holding at >600m [3] | -1.419 | 1.739 | -1.317 | 1.557 | -.677 | 1.598 | -.841 | 1.583 |
| Less Favoured Area 1 – All Land inside SDA [4] | .036*** | 0.011 | .309 | .948 | .374 | .973 | .338 | .965 |
| Less Favoured Area 2 – All Land inside DA [4] | 1.345* | 0.803 | .988 | .925 | 1.554* | .940 | 1.499* | .940 |
| Less Favoured Area 3 – 50%+ Land in LFA of which 50%+ in SDA [4] | .791*** | 0.101 | .860*** | .090 | .798 | .928 | .751 | .921 |
| Less Favoured Area 4 – 50%+ Land in LFA of which 50%+ in DA [4] | .751 | 1.091 | -.012 | .976 | 1.132 | 1.001 | 1.127 | .993 |
| Less Favoured Area 5 – <50% Land in LFA of which 50%+ in SDA [4] | -.541 | 1.717 | -.467 | 1.537 | -.560 | 1.577 | -.545 | 1.564 |
| Less Favoured Area 6 – <50% Land in LFA of which 50%+ in DA [4] | -.399 | .999 | -.531 | .894 | .017 | .917 | -.063 | .910 |
| Constant | 72.597*** | 31.231 | 85.416*** | 25.689 | -76.965** | 37.441 | -61.625** | 35.701 |

2 : Estimates obtained by Translog Profit Function; 3 : Reference Category 'Most of Holding <300m'; 4 : Reference Category 'All Land Outside LFA'; *,**,*** : Significance at 10%- , 5%- , or 1%-Level;
5: Bootstrapped SE

*Table A7 cont.*

| *Dependent Variable* | Cost Ratio 4C | | CR 1C | | CR 2C | | CR 3C | |
|---|---|---|---|---|---|---|---|---|
| *Random Effects Parameters* | *est* | *se* [5] | *est* | *se* | *est* | *se* | *est* | *se* |
| Government Office Region (n = 8) [5] | | | | | | | | |
| Standard Deviation (Constant) | 85.332*** | 24.334 | 73.161*** | 21.214 | 105.338*** | 29.458 | 97.636*** | 28.119 |
| County (n = 65) [5] | | | | | | | | |
| Standard Deviation (Constant) | 36.875*** | 3.771 | 26.544*** | 3.768 | 37.577*** | 6.433 | 35.734*** | 4.322 |
| Time (n = 607) [5] | | | | | | | | |
| Standard Deviation (Constant) | 117.635** | 43.965 | 83.371*** | 31.207 | 107.562** | 54.182 | 93.631** | 34.981 |
| Standard Deviation (Residual) | 6.335*** | .091 | 5.672*** | .081 | 5.818*** | .083 | 5.772*** | .083 |
| Likelihood-Ratio Test / Chi2(3) ($H_0$ : Non-Linear Functional Form) | 11042.56 / 0.000 | | 10561.12 / 0.000 | | 11490.27 / 0.000 | | 11461.62 / 0.000 | |
| Log-Restricted Likelihood | -8528.236 | | -8243.363 | | -8327.2111 | | -8306.6758 | |
| Wald Chi2(52) / Prob > Chi2 | 17999.08 / 0.000 | | 31767.54 / 0.000 | | 31990.49 / 0.000 | | 30855.68 / 0.000 | |
| Bootstrap Replications | 1000 | | 1000 | | 1000 | | 1000 | |
| Number of Observations | 2286 | | 2286 | | 2286 | | 2286 | |

5 : Single-Variable Random-Effects Specification; Covariance Structure set to Identity; *,**,*** : Significance at 10%- , 5%- , or 1%-Level; 5: Bootstrapped SE

[1] This research has been completed when the first author was an ESRC funded research fellow in the Department for Environment, Food and Rural Affairs, London, UK (ESRC: RES-173-27-0097). The views expressed herein are those of the authors and not necessarily of DEFRA. Errors remain the authors' own responsibility.

[2] We use "landowner" to denote any entity that is in the position (de jure or de facto) to supply environmental services through its influence on an ecosystem. The term "conservation agent" refers to any entity that encourages landowners to supply such environmental services (see also Ferraro 2008).

[3] Hidden information has been the subject of numerous theoretical analyses in the context of agri-environmental payment schemes (see e.g. Spulber 1988, Chambers 1992, Bourgeon et al 1995, Fraser 1995, Wu and Babcock 1996, Latacz-Lohmann and Van der Hamsvoort 1997, Moxey et al 1999, Ozanne et al 2001, Peterson and Boisvert 2004, Ozanne and White 2008). Ferraro (2008) points out that PES programs may also serve as an instrument for income redistribution and thus reducing informational rents to landowners which may have implications for other policy goals associated with such programs.

[4] The problem of moral hazard in agri-environmental payment schemes has been also the subject of a number of theoretical studies (see e.g. Choe and Fraser 1998 and 1999, Ozanne et al 2001, White 2002, Fraser 2002 and 2004, Hart and Latacz-Lohmann 2005, Ozanne and White 2008, Yano and Blandford 2009, Zabel and Roe 2009).

[5] $F(x)$ measures cumulative probability mass and hence tells us the proportion of farms for which $c_i<x$. It is apparent that $F(.)$ must lie between zero and one and must be everywhere (weakly) increasing in its argument.

[6] To find that level we go to the point at which the marginal cost and marginal revenue functions cross. Fixed costs (and by implication total costs) do not have an impact on this decision because they do not affect anything at the margin (see Heyes 1998).

[7] There is a vast literature on PES in general and AES in specific. We report only the most important onse with respect to the analysis performed in this study. Other interesting studies on acceptance and compliance with respect to AES include Hodge (2000), Harvey (2003), Burton et al. (2008), and Vatn (2009).

[8] McWilliams and Zilberman (1996) point out, that potential participants use the gained information to update their posterior expectations and beliefs about the new scheme over time in a Bayesian manner.

[9] Whitby and Saunders (1996) compare two such agreements for the UK (the Environmentally Sensitive Areas ESA and the Sites of Special Scientific Interest SSSI) on the basis of transaction costs and public expenditures and estimate supply curves based on cost per hectare ratios. McCann and Easter (1999) measure the magnitude of transaction costs associated with different policies to reduce agricultural nonpoint source pollution by using staff interviews to disentangle the instruments' transaction costs. Falconer and Whitby (2000) investigate factors for scheme administration costs at EU level and try to indicate potential for implementation cost savings. They conclude that downward pressure on costs over time may stem from economies of scale and experience. Falconer et al (2001) aim to estimate administrative cost functions to investigate factors affecting the magnitude of such costs. They use panel data for the ESA scheme in the UK and find that the extent of participation is important in explaining administrative cost variability across space. Further economies of size were found with respect to the number of agreements and a significant effect of scheme experience. McCann et al (2005) provide a systematic treatment of transaction cost definition and measurement as well as make recommendations regarding a typology of costs and potential measurement methodologies. Other empirical studies focus on the macro level and try to estimate the optimal level of conservation in the context of agri-environmental schemes (e.g. Waetzold and Schwerdtner 2005, Waetzold et al 2008).

[10] Measured magnitudes rage from 8% of water purchase cost for the California Water Bank (Howitt 1994) up to 38% of total costs for an agricultural technical assistance program (McCann and Easter 2000). There is also a large literature, following Williamson (1985) empirically demonstrating that transaction cost minimization can help explain industry structure and decision making by economic agents in the context of market transactions (e.g. Pittman 1991, Leffler and Rucker 1991, Lyons 1994, Moss et al. 2001).

[11] McCann et al (2005) note that there might be a number of disadvantages of such data: incomplete coverage of types of costs; not well-organized data for research purposes in that it may be difficult to separate out transaction costs for different policies, or to clearly separate transaction costs from abatement costs; requirement for cooperative agency contacts willing to pull together information; confidentiality issues; and can only be used for ex post studies. Access to the necessary data is a major problem faced by researchers examining transaction costs. Private and public sector managers are understandably suspicious about the collection of information that may reflect unfavorably on them or their programs.

[12] E.g. the analysis by Whitby and Saunders (1996) is not based on a comprehensive multivariate framework whereas the study by Falconer et al (2001) does not consider cost factors on farm and farmer level. Quillerou and Fraser (2009) base their regression analysis on 46 observations. All of these studies neglect the cost implications of risk related variation in farmers' compliance behaviour.

[13] See also Falconer et al (2001).

[14] Assuming that farmer i is a profit maximising agent.

[15] The French scheme 'Contrats Agriculture Durable' marks the opposite trend towards more geographically differentiated agri-environmental measures.

[16] Chaplin (2009) shows that many ELS agreements are focused around a very limited number of options. The 6 most popular options in the scheme account for 49% of all points scored. The 20 most popular options account for 90% of all the points scored within the scheme. The remaining 42 options account for only 10% of the points scored within the scheme. 15% of all ELS agreements score more than 70% of their points from lowland grassland options, with 9% scoring over 90% of their points from this option group. 6% of all ELS agreements score 70% or more of their points from boundary options. Combining boundary and lowland grassland options together 40% of all ELS agreements score more than 70% of their points from boundary and lowland grassland options alone, including almost 20% who score in excess of 90% of their points from these two option groups.

[17] Although individual files on participating farms agreements' were available, these could not be linked to farm level data as confidentiality agreements largely prohibit the identification of individual farms. Further, it has to be stressed that the administrative costs incurred in direct relation to the ESS scheme are generally not precisely costed. Challenges to measuring organisation costs relate, for example, to the low separability of administrative functions at the level of any particular agency (see also Falconer et al 2001).

[18] The statistical software STATA 10.0 is used to estimate the model.

[19] That is, imposing linear homogeneity on an input (output) distance function requires normalizing the inputs (outputs) by the input (output) appearing on the left hand side of the estimating equation. This raises issues not only about what variable should be chosen as the numeraire, but also about econometric endogeneity because the right hand side variables are expressed as ratios with respect to the left hand side variable. Although a common approach in input distance function-based agricultural studies is to normalize by land (e.g., Morrison-Paul and Nehring, 2005), to express the function in input-per-acre terms, this is questionable when a key issue to be addressed is whether different kinds of farms with potentially different productivity use land more or less intensively.

[20] E.g. taking logs of variables which would lead to modelling problems based on zero values (see Battese 1997).

[21] We also tested for other groupings with respect to the random effects specification (e.g. time, farm etc.), however, none of these showed to be of satisfactory significance. The insignificane of a time based random coefficients specification is in line with the findings for the random effects specification for the underlying regression though.

[22] The diagnostic measures for the risk related translog profit function estimation as well as the technological transformation frontier estimation indicate satisfactory model fits and no severe signs of misspecification. The detailed estimates and model statistics for these two estimation steps are not reported here due to space limitations and readability, however, can be obtained from the authors upon request. *Endogeneity*: Potential endogeneity with respect to some explanatory variables in the cost regressions is addressed by incorporating also variables for environmental, spatial and socioeconomic characteristics at the stage of the estimations of the risk and technological proxies. Hence, the risk and technological estimates used at the stage of the final cost regressions are unbiased estimates. *Collinearity*: Potential collinearity between the different farm related technological variables at the stage of the cost regressions has been tested for by additional auxiliary regressions. Hence, we have regressed each explanatory on all other explanatories and have critically examined the model significance. However, as the robust farm type indicator variables are defined by the survey agency purely on relative output share considerations whereas the elasticity and performance estimates are based on multivariate estimations and marginal derivations at the point of optimisation, the probability of potential correlations between these regressors are rather low. Finally, such potential misspecifications based on variables correlations are also addressed by the mixed-effects modelling set-up.

[23] This perspective differs from the robust type perspective as here the point of optimal production is considered and not the annual share of primary output as used for the FBS farm categorization.