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ESS versus NVZ – The Cost-Effectiveness of Command-and-Control versus Agreement Based Policy Instruments

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Abstract

This study empirically investigates the cost-effectiveness of different agri-environmental policy instruments. We compare the Environment Stewardship Scheme (ESS) as an example for a management agreement type instrument, to the Nitrate Vulnerable Zones (NVZ) as an example for a command-and-control type instrument. Both instruments are currently applied in the UK. Based on a simple cost model considering also relevant transaction costs and risk we use different regression and resampling techniques to estimate the marginal effects of different factors with respect to the instruments' relative cost-effectiveness 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. The findings suggest that the ESS instrument has a higher cost-effectiveness whereas the NVZ instrument is more expensive on a general level. However, if the focus is on compliance weighted cost ratios, the picture changes somewhat. Further, we find a significant regional variation in the cost-effectiveness for both instruments as well as a significant variation over time.

Keywords: Agri-Environmental Instruments, Costs, Risk

ESS versus NVZ – The Cost-Effectiveness of Command-and-Control versus Agreement Based Policy Instruments*

I) Introduction

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. Following standard economic theory, such agri-environmental goods (e.g. water quality or biodiversity) are unlikely to be provided through a market mechanism at their socially optimal levels because of externalities as well as the public good nature of the targeted goods. However, market based policy instruments are generally considered as a more cost-effective way to achieve environmental goals compared with command-and-control based policy instruments. The overall aim of this study is to empirically investigate the costs and effects of a management agreement type agri-environmental instrument and compare them to the cost and effects of a command-and-control agri-environmental instrument.

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). 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. We first 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. Second, we consider the case of the Nitrate Vulnerable Zone Scheme (NVZ) as a command-and-control type instrument. The Nitrate Pollution Prevention

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Regulations 2008 have been introduced to implement the EU's Nitrates Directive and to reduce nitrogen losses from agriculture to water. Areas where nitrate pollution is a problem are designated as NVZ and rules are set for certain farming practices to be followed in these zones.

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. The next section discusses the economics of a management-agreement-type and a command-and-control type instrument followed by section 3 introducing the different costs and effects related to policy measures in general and agri-environmental instruments in particular. Section 4 describes the Environmental Stewardship Scheme and the Nitrate Vulnerable Zone Scheme operated in the UK. 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.

II) Agri-Environmental Instruments

Considering instruments of economic policy at a very general level, economic instruments can be distinguished from traditional command-and-control instruments (see 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. Such contractual relationships are subject to asymmetric information between landowners and conservation agents.

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. 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, 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). 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 (see e.g. White 2002, Fraser 2002 and 2004, Hart and Latacz-Lohmann 2005, Ozanne and White 2008, Yano and Blandford 2009, Zabel and Roe 2009).

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 η, and the penalty for non-compliance is p, then a profit-maximising and risk neutral farm will comply if and only if

$$c_i \leq \eta p \quad (1)$$

or

$$\eta p - c_i \geq 0 \quad (2)$$

Those farms that find

$$\eta p - c_i \geq t_i \quad (3)$$

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 ηp. 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 γ_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, γ_j, can be expressed as a function of the enforcement policy parameters

$$\gamma_j = F(\eta p) \quad (4)$$

By raising η - 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 γ_j increases. The magnitude of such an increase (i.e. the effectiveness of a raise in η and/or p) will depend on the shape of F. Assuming social disutility as the sum of the unweighted sum of all AES scheme costs and environmental damage, compliance decisions will be firstbest if and only if the product ηp happens to equal the marginal expected environmental damage caused by non-compliance. For any given scheme population compliance rate γ_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 η and p as high as possible. Full compliance is only ensured if ηp 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.[i] 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

$$c(ch_i) + p(ch_i - s) \quad (5)$$

The first-order condition provides the solution ch_i^*

$$c'(ch_i^*) = -p'(ch_i^* - s) \quad (6)$$

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, 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. 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. Peterson and Boisvert (2004) propose a method to accommodate asymmetric information on farmers' risk preferences in designing voluntary environmental policies. By incorporating stochastic efficiency rules in a mechanism design problem, the conservation agent could find incentive-compatible policies by knowing only the general class of risk preferences among the farmers. 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. 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. 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, (ii) misjudgement, (iii) penalty leverage, or (iv) regulatory dealing. 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.

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. 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 (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 $f(\cdot)$. Beside price risk, the individual farmer is assumed to incur production risk as crop and livestock yields and product 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 ε with its distribution $H(\cdot)$ 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 $q = f[\psi(\alpha)x_{ch}, \mathrm{x}]$ where α 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 ϖ described by (7)

$$\max_{\mathbf{x},x_{ch}} E[U(\varpi)] = \max_{\mathbf{x},x_{ch}} \int\{U[pf(\mathbf{x},\varphi(\alpha)x_{ch},\varepsilon) - \mathbf{r}'\mathbf{x} - r_{ch}x_{ch}]\}dH(\varepsilon) \qquad (7)$$

where $U(\cdot)$ 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

$$E[r_{ch}U'] = E\left\{p\frac{\partial f(\varepsilon,\varphi(\alpha)x_{ch},\mathbf{x})}{\partial x_{ch}}U'\right\} \Leftrightarrow \frac{r_{ch}}{p} = E\left\{\frac{\partial f(\varepsilon,\varphi(\alpha)x_{ch},\mathbf{x})}{\partial x_{ch}}\right\} + \frac{cov[U';\frac{\partial f(\varepsilon,\varphi(\alpha)x_{ch},\mathbf{x})}{\partial x_{ch}}]}{E[U']} \qquad (8)$$

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. Consequently, empirical knowledge about farmer *i's* risk preferences leads to lower agency costs via more effective scheme design based on targeted compliance incentives for farmer *i* (see also Peterson and Boisvert 2004).

III) 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. Whitby and Saunders (1996) compare two such agreements for the UK 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 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.

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. 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.[ii] Although the magnitudes of transaction costs associated with environmental and natural resource policies are demonstrably important (Kuperan et al. 1998, Falconer et al. 2001), few studies to date have attempted to actually quantify transaction 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, McCann et al 2005). 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. 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). McCann et al (2005) based on Thompson (1999) present a general typology of transaction cost components associated with public policies: (1) research, information gathering, and analysis associated with defining the problem; (2) design and implementation of the policy; (3) enactment of enabling legislation, including lobbying and public participation costs; (4) contracting costs, which may include additional information costs, bargaining costs, and decision costs, which are relevant when a market has been set up for a natural resource; (5) support and administration of the ongoing program; (6) monitoring/detection, which may include both the monitoring of the environmental outcome, or the level of compliance with the regulation, tax/subsidy scheme, or private contract, as well as the development of monitoring technologies; and (7) prosecution/ enforcement/inducement/conflict resolution costs incurred if lack of compliance is found; (8) scheme analysis and (9) scheme revision. 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. So far there is no contribution which empirically investigates the link between instruments' costs and farmers' behaviour, 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.[iii]

A Simple Management Scheme Cost Model

Let *TC* denote the sum of scheme *j* related transaction cost components - fixed and variable costs for the set-up (*SU*), administration (*A*), monitoring (*M*), and scheme evaluation (*E*) for the time period t = 1, ..., T:

$$TC_{jt} = \sum_{t=1}^{T}(SU_{jt} + A_{jt} + M_{jt} + E_{jt}) \tag{9}$$

The total scheme costs *SC* (or exchequer relevant costs) 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 *sc* and factors related to scheme *j's* farmers' compliance behaviour *c*

$$SC_{jt} = CP_{jt}(sc_{jt}) + TC_{jt}(sc_{jt}, c_{jt}) = F_{jt}(sc_{jt}, c_{jt}) \tag{10}$$

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*). Abstracting from *j* and *t*, we obtain

$$SC = F(aagr, nagr, st, z, in, m, tech, l, att) \tag{11}$$

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. To elicitate proxies for these technological characteristics and performance measures a multi-output framework can be used. To obtain estimates of the production structure and performance of each farm participating in the scheme we 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 $0=F(\mathrm{Y,X,C})$, 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:

$$Y_{P,it} = F(Y_{it}, X_{it}, C_{it}, V_{it}, U_{it}) \quad (12)$$

where the subscript P denotes the primary output of farm i at time t. By adding V_{it} as a vector of random errors following iid N(0, s_v^2), and 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 (12) yields an efficiency estimate per farm and year (eff_{it}) 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 ϖ 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*:

$$\omega_{it} = F(R_{it}, P_{it}, C_{it}, V_{it}) \quad (13)$$

The estimated moments (μ_o) of the profit function in (13) can be used as proxies for the individual farmer's production risk and deliver empirical evidence on his risk related behaviour, hence, also his compliance behaviour with scheme *j's* contractual requirement. 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)

$$SC_{c,jt} = F(\cdot)_{jt} \quad (14)$$

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*)

$$SC_{c,gor,jt} = F(\cdot)_{gor,jt} \quad (15)$$

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

$$\left(\frac{SC_c}{ha}\right)_{gor,jt} = F(\cdot)_{gor,jt} \quad (16)$$

A Simple Command-and-Control Cost Model

For the command-and-control type policy instrument we slightly modify the previously outlined cost model (equations 9 to 16). Hence, as no compensatory payments are relevant in this case equation (10) is to be modified

$$SC_{jt} = TC_{jt}(sc_{jt}, c_{jt}) = F_{jt}(sc_{jt}, c_{jt}) \quad (17)$$

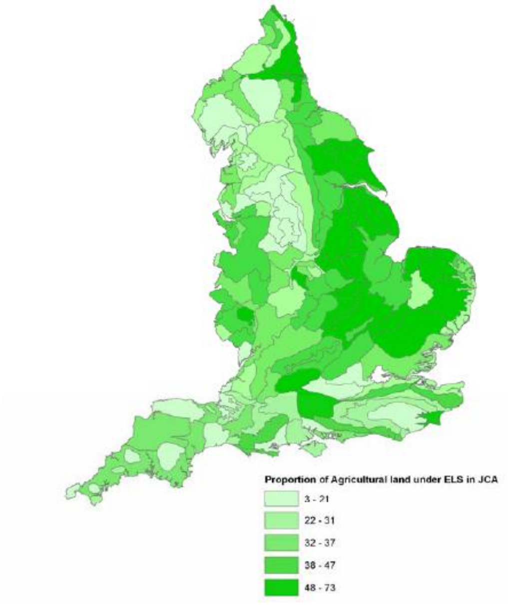
where the total scheme costs *SC* (or exchequer relevant costs) for instrument *j* in year *t* comprises only the sum of transaction costs *TC* and is again a function of instrument related factors *sc* and factors related to instruments *j's* farmers' compliance behaviour *c*. The rest of the notation is equivalent to those outlined above. Furthermore the estimation of production structure and risk related parameters will follow the procedures outlined above. Finally, the consideration of average instrument costs and environmental effects are defined along the explanations above for the conservation scheme.

IV) Empirical Cases

The Environmental Stewardship Scheme (ESS) in the UK

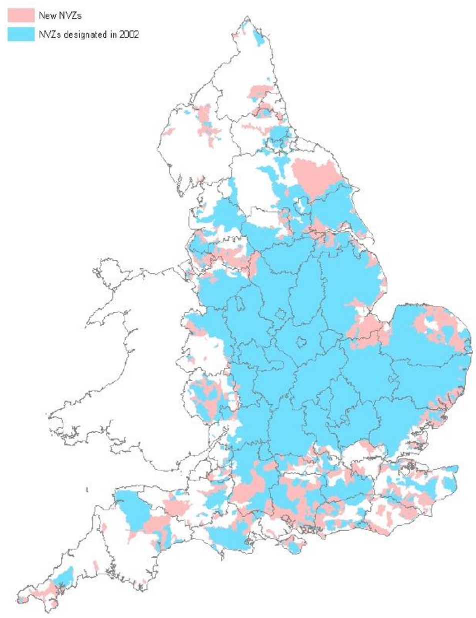
The need for society to engage farmers in conservation activities has been officially acknowledged in the EU Common Agricultural Policy (CAP) since the beginning of the 1990s. The McSharry reform in 1992 led to the widespread implementation of agri-environmental measures in the CAP. Since then, voluntary agri-environmental schemes have become a key policy instrument for conserving and enhancing the environment. 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). The UK 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 (map 1). 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). 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.

Map 1 - Geographical Variation in ELS Uptake



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

Map 2 - Nitrate Vulnerable Zones (NVZ)



(Based on ADAS 2007)

The Nitrate Vulnerable Zones (NVZ) in the UK

The Nitrate Pollution Prevention Regulations 2008 have been introduced to implement the ECs Nitrates Directive and to reduce nitrogen losses from agriculture to water. Areas where nitrate pollution is a problem are designated - known as Nitrate Vulnerable Zones (NVZs). Rules are set for certain farming practices to be followed in these zones. In 2006 the agricultural area designated as NVZs has been increased to about 68% (see map 2). The owner or occupier of any land or holding within an NVZ is responsible for complying with the rules whereas the Environment Agency is responsible for assessing farmers' compliance with these regulations, accomplished by random farm visits. Compliance with these rules is a requirement for cross compliance under SPS. Nitrate Vulnerable Zones rules concerning e.g. the storage of organic manures, the limiting of livestock manure, the planning of nitrogen use, the limiting of N requirements with respect to crop production, the management of spreading periods for organic manures and manufactured fertiliser, the nitrogen impact on surface water, and different field application techniques.

Different studies aim to evaluate the environmental effects of the NVZ programme (see Defra 2007). However, economic costs and effects are included only at the sectoral level in these studies. In contrast to this practise we focus the direct set-up and operating costs of the NVZ instrument. E.g. ADAS (2007) comprehensively estimates the final environmental effects of the NVZ instrument by covering in detail the nutrient content of manure, the pollutant losses, and the livestock manure N loadings. We conclude, that the final environmental effects can not satisfactorily be separated from other instruments' environmental effects with respect to the nitrate pollution reduction policy goal. This appears even more difficult if these effects should be covered on a regional basis and/or in a dynamic perspective, e.g. on annual basis. We therefore use a proxy for the final environmental effects on a more aggregated level, i.e. the utilised agricultural area covered by instrument (per region and year). However, we note that the implied assumption is that the final environmental effect is the same per ha for the different instruments over time and space.

V) Data and Empirical Methodology

By empirically investigating the cost models outlined above, 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 policy instruments 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 instruments and 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.

Data

In contrast to earlier studies 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, Natural England and The Environment Agency) as well as internally recorded scheme performance data, hence, consists of expert informed proxies and calculations. We use the share of agreements including nitrate relevant ESS options as a weight to build cost proxies at the regional level for the ESS scheme. 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. 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. 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. 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. 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.

With respect to the NVZ scheme we use annual data on the different transaction cost components with respect to the period 2006 to 2008. The observations are collected at the Environmental Agency defined regional budget level (i.e. Anglian, Midland, North East, North West, South West, Southern, Thames and Wales).[iv] 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 and/or located in an NVZ area across England in the years 2006 to 2008 (see table A1).

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 ϖ on a vector of variable input prices *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*:

$$\omega_{it} = \varphi(\mathrm{R}_{it}, P_{\mathrm{it}}, \mathrm{C}_{it}; \beta) + v_{it} \tag{18}$$

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

$$ln\omega_{it} = \alpha_0 + \sum \alpha_j lnR_{ij} + \alpha_l lnP_{il} + 1/2 \sum \alpha_{jk} lnR_{ij}\, lnR_{ik} + 1/2 \sum \alpha_{jl} lnR_{ij}\, lnP_{il} + \sum \beta_m\, C_{im} + v_{it} \tag{19}$$

where $v \sim N(0, \sigma^2)$. The *o*-th central moment of profit conditional on input use is defined as

$$\mu_o(\cdot) = E\{[\omega(\cdot) - \mu_1]^o\} \tag{20}$$

where μ_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 (19), which gives

$$\hat{v}_i^2 = \vartheta(\mathrm{r}_{it}, p_{\mathrm{it}}, \mathrm{c}_{it}; \delta) + v_{it} \quad (21)$$

and by estimating (21) we obtain consistent and efficient estimates of the variance (2nd 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). 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 models in (19) and (21) are estimated by applying Ordinary Least Squares treating the dataset as pooled yearly cross-sections.[v]

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. 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. 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 $0=F(\mathrm{Y,X,T})$, 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. Accordingly, we estimate the transformation function $Y_1= G(\mathrm{Y}_{-1},\mathrm{X,C})$, where, Y_1 is the primary output of the farm and 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 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. We use the generalized linear functional form suggested by Diewert (1973) to avoid any mathematical transformations of the original data. The model can be described as:

$$Y_{P,it} = F(Y_{it}, X_{it}, C_{it}) = \alpha_0 + 2\alpha_{0S}Y_S^{0.5} + \sum 2\alpha_{0k}X_k^{0.5} + \alpha_{SS}Y_S + \alpha_{kk}X_k$$

$$+\sum \alpha_{kl} X_k^{0.5} X_l^{0.5} + \sum \alpha_{kS} X_k^{0.5} Y_S^{0.5} + \beta_t T + \beta_{tt} T + \sum \beta_{kt} X_k^{0.5} T + \sum \beta_{kt} X_k^{0.5} T + \beta_{St} Y_S^{0.5} T + v_{it} - u_{it} \quad (22)$$

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 Y_{-1}, X is a vector of X_k inputs land, labor, fodder, veterinary and medical expenses, seed, fertilizer, crop protection expenses, capital, livestock, 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} ~$N(m_{it}, s_u^2)$ as the inefficiency term per farm and year (see Battese and Coelli 1995).

Modelling III: Estimating Instruments' Cost Effects

The previously calculated average cost ratios are used to estimate the cost-effectiveness of the ESS scheme and the NVZ instrument at a regional level within a regression framework. Following equation (16) the different cost ratios are regressed on: A as a vector of administrative indicators at the 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:

$$CER_{it} = \alpha_0 + \sum \epsilon_j A_{ijt} + \sum \theta_k E_{ikt} + \sum \zeta_l F_{ilt}^* + \sum \eta_o R_{iot}^* + \sum \vartheta_q S_{iqt} + v_{it} \quad (23)$$

for farm i in time period t. 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 (step 1) and the estimation of the transformation frontier (step 2). We estimate the model specified in equation (23) applying first a random effects generalized least squares (GLS) procedure according to

$$CER_{it} = \alpha_0 + \sum \epsilon_j A_{ijt} + \sum \theta_k E_{ikt} + \sum \zeta_l F_{ilt}^* + \sum \eta_o R_{iot}^* + \sum \vartheta_q S_{iqt} + \mu_i + v_{it} \quad (24)$$

for farm i in time period t, where the variables and parameters are specified as above and μ_i are the random effects with a normal distribution based on mean zero and constant variance (models NVZ1 and ESS1). Second, we estimate the model in (24) by applying a random effects GLS estimator and allowing for a first-order autoregressive disturbance term according to

$$v_{it} = \rho v_{i,t-1} + e_{it} \quad (25)$$

where |rho| < 1 and e_{it} is independent and identically distributed (i.i.d.) with zero mean and variance sigma_e*sigma_e. This model maintains the assumption that the μ_i are independent of the x_{it} by also accomodating covariates that are constant over time (see e.g. Baltagi and Wu 1995). Further, this model allows for the consideration of lagged behaviour with respect to scheme management but also with respect to participation and compliance related behaviour at the individual farm level (models NVZ2 and ESS2).[vi]

Finally a bootstrap based resampling estimation procedure is applied to receive evidence on the statistical robustness of the estimated standard errors (see e.g. Horowitz 2001).

VI) Results and Discussion

All models estimated show a reasonable overall statistical significance. Additional diagnostic and quality tests have been conducted for the regressions and are reported in the appendix (see tables A3 and A4). In addition, the bootstrapped standard errors for the different cost ratios and estimated parameters show a high level of robustness. [vii]

ESS versus NVZ

The estimated cost ratios show that the ESS scheme has a higher cost-effectiveness compared to the NVZ scheme in general (conditional on the per ha measure we use, the time period considered and the cost data provided). The NVZ scheme appears to be more "expensive" at a general level. However, if the focus is on the compliance weighted cost ratios this statement has to be further qualified: The mean cost per ha are more or less the same for the two instruments over the period 2006 to 2008 considered (see also table 1).

Table 1 - Bootstrapped Descriptive Statistics for ESS and NVZ Cost Ratios

Cost-Ratio *(GBP per ha and year)*	Regional Level	Time Period	Mean	Standard Deviation	Minimum	Maximum	95% Confidence Interval for Mean (Bias Corrected)	
Cost Ratio ESS	GOR	2006 - 2008	105.891	35.942	25.912	171.082	103.633	108.118
Cost Ratio ESSc	GOR	2006 - 2008	162.621	110.176	27.351	470.475	155.703	169.539
Cost Ratio NVZ	EA region	2006 - 2008	128.552	65.552	57.089	277.331	126.561	131.048
Cost Ratio NVZc	EA region	2006 - 2008	163.836	88.045	65.124	380.389	160.496	167.177

(GOR - government office region: 27 obs; EA - Environmental Agency region: 28 obs; 10,000 Bootstrap Replications; c - compliance weighted)

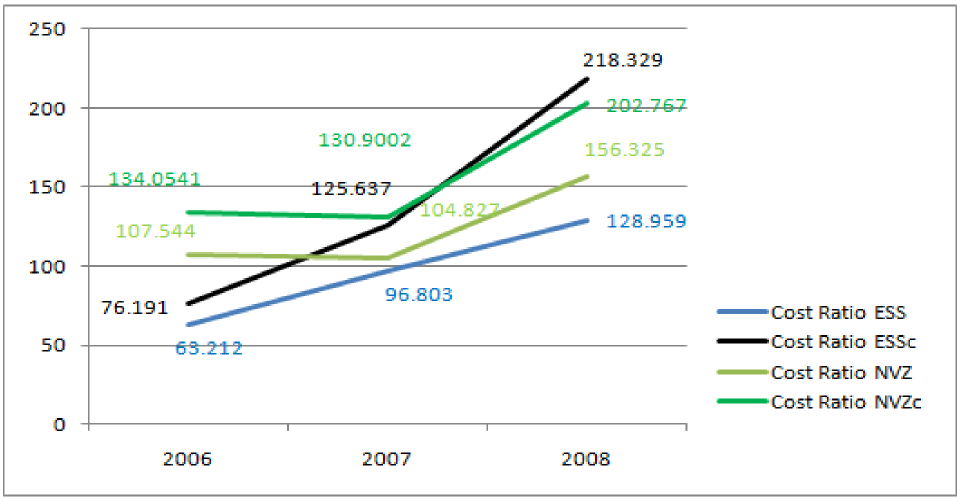
Regional Variation

The results show that the cost-effectiveness for the two instruments significantly varies at a regional level for the weighted and unweighted cost ratios. The definition of the administrative borders for the individual instrument's management are crucial for its cost-effectiveness.

Variation over Time

The descriptive statistical results show for the NVZ instrument a significant decrease in cost per ha in the year 2006 as an increased area has been covered by the scheme. For the ESS scheme the descriptive results suggest a steady cost increase over time. It is evident that this cost increase is more pronounced for the compliance weighted cost ratio where the ESS scheme appears to be less cost-effective than the NVZ scheme in 2008. The increase in schemes' related cost per ha has been also driven by a decreasing compliance rate over all participating farms per region and year which is illustrated by figure 1. Given these findings we can conclude that the cost-effectiveness significantly varies over time for both instruments with a decrease in cost-effectiveness for the ESS scheme and mixed evidence for the cost-effectiveness of the NVZ scheme. These partial descriptive findings are backed up by the estimated coefficients for the time indicator variable (see tables A3 and A4). The coefficient is significantly positive over all cost models estimated, i.e. that the costs per ha significantly increase over time, and to a clearly higher extent for the compliance weighted costs.

Figure 1 - Development of Instruments' Cost per ha in 2006 to 2008 (GBP per ha)



With respect to the management agreement type instrument 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 ESS 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, for both type of instruments changes in the mix of administrative activities are needed, linked to the time profile of 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.

Technology and Performance

The regression results show a positive and significant cost effect for horticultural farms, pig farms and mixed type farms. But a negative and significant cost effect for dairy and cropping farms. The degree of farm specialisation, the value of the rental equivalent ratio, the level of technical efficiency and the amount of organic production showed to have a positive cost effect for the ESS scheme. A negative cost effect was found for the amount of off-farm income generated, the value of the debt to assets ratio, and a higher subsidies to gross margin ratio. The regression based estimates show firther a positive and significant cost effect for horticultural farms, lowland grazing farms, and mixed type farms, however, a negative and significant cost effect for lfa grazing farms, cropping and dairy farms. In addition we found a positive cost effect for the technical efficiency level of the farm, the amount of organic production, the value of the farm's rental equivalent, and the degree of farm specialisation. On the other hand a negative cost effect for off-farm income, the share of hired labor, the value of the farm's debt to assets ratio, and the value of the subsidies to gross margin ratio. With respect to the compliance weighted NVZ scheme cost ratios the descriptive statistical results show the lowest cost effectiveness for other type and cropping farms, but the highest cost effectiveness for dairy, poultry and lowland grazing farms. The regression based estimates show a negative and significant cost effect for pig and cereal type farms, a positive and significant cost effect for the amount of shared hired labor used on the farm, but a negative and significant cost effect for the amount of organic production by the farm.

We could not find any significant effect by the value of total sales as well as other performance indicators as e.g. the debt to asset ratios. The rate of technical efficiency of the farms, however, shows generally a positive cost effect but differing results for the command-and-control and the management agreement type models. Consequently, evidence for adverse selection is found only in the case of the unweighted NVZ scheme 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 put under the scheme. Based on these findings we formulate the following preliminary conclusions: (1) The cost-effectiveness of both instruments is the highest for cropping farms, which suggests that these farms might be more risk averse than others. (2) Dairy farms might respond more effectively to a management agreement-type instrument. (3) Farms with a significant amount of off-farm income and farms with a higher subsidies to gross margin ratio show a significantly higher cost-effectiveness for the management agreement-type instrument. (4) A technically more efficient farm appears to respond more cost-effectively to the NVZ instrument. (5) The higher the share of organic production, the more cost-effective the ESS instrument. (6) For farms with a high rental equivalent ratio, the NVZ instrument seems to be more cost-effective. (7) The more specialised the farm production the less cost-effective agri-environmental instruments seem to be.

Locational Characteristics

The regression estimates show mixed cost effects for farms located in less favoured areas, but a positive cost effect for farms located at higher altitudes (corresponding to FBS type alt2 and alt3) for the NVZ instrument. With respect to the ESS scheme the results reveal a negative and significant cost effect for farms located in semi-high areas (corresponding to FBS type alt 2) and for farms with all land inside SDA (corresponding to FBS type lfa2). For the compliance weighted ESS scheme the regression results suggest a negative significant cost effect for farms with all land inside severely disadvantaged areas (SDA) or farms with all land inside disadvantaged areas (DA, corresponding to FBS types lfa2 and lfa3). 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 weighted NVZ scheme costs. However, these findings are the opposite for the unweighted ESS scheme indicating that the average altitute of the farm location has a significant positive effect for the cost-effectiveness of the management agreement type instrument. Further, the findings suggest that compliance behaviour might be not related to spatial heterogeneity. With respect to the Less Favoured Area (LFA category 7) indicators we found that the more farmland is part of such an area, the higher are the average costs per ha under the NVZ scheme. This could simply indicate that most NVZ areas are designated in less favoured areas, hence, the probability of being located in such a zone is simply much higher for LFA farms. The opposite result was found for the weighted ESS scheme's cost: Here the estimates suggest that the more land a particular farm has inside an SDA or DA (LFA categories 2 and 3) the lower are the costs for the ESS scheme per ha. 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 inclusion of a substantial area of non LFA land in the ESS may increase administrative costs through increasing the complexity of negotiating management agreements. This would be not the case for land in severely disadvantaged areas as here the ecosystem services provided by the land are more presumably more uniform (see also MacFarlane, 1998). Based on these findings we can conclude: (1) A management agreement type instrument is more cost effective in less favoured areas. (2) Farmers in less favoured areas show a higher compliance with an agreement type instrument. (3) A command and control type instrument is more costly at higher altitudes.

Socio-Economic Characteristics

The regression estimates show for the NVZ and NVZ compliance weighted cost ratios a negative cost effect for education, i.e. the better educated the farmer the lower the costs of the instrument per ha. On the other hand the results also show a positive cost effect for the amount of off-farm income generated. For the ESS and ESS compliance weighted cost ratios a positive cost effect for age was found, i.e. the younger the participating farmer the lower the costs of the ESS instrument per ha. However, we found a negative cost effect for the amount of off-farm income generated. These findings indicate 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 negative correlated with the average ESS scheme costs for the compliance weighted and unweighted models (differing from the NVZ cost effects). This could suggest 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 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. Based on these findings we formulate the following preliminary policy conclusions: (1) Age has a different effect on the instruments cost effectiveness: Younger farmers are more likely to respond positive to/and comply with management agreement type policies. (2) A higher level of education contributes to a higher cost effectiveness of command and control type policies. (3) Off farm activities have different implications for the instruments' cost effectiveness: A management agreement type instrument is more effective for part-time farmers.

Risk

The regression results show for the NVZ scheme a positive cost effect of all profit related distributional moments (i.e. risk proxies). Further, the higher the level of the farner's education, the higher the amount of off-farm income generated, the higher the degree of the farm's specialisation the lower the negative effects of the risk proxies' on the scheme's cost effectiveness. In addition the estimates reveal that the size of the farm increases the cost effects of risk, time on the other hand shows to have mixed effects on the risk proxies' cost implications. For the ESS scheme the regressions suggest a negative cost effect of the profit related distributional moments (i.e. risk proxies) whereas the age (i.e. experience) of the farmer and the size of the farm size both show a compensating effect on the risk proxies' cost effects. The amount of off-farm income generated increases the cost effects of risk, and time again shows to have mixed effects on the risk proxies' cost implications. The regressions show for the ESS scheme further that controlling for scheme compliance lead to a less pronounced cost effect for the risk proxies, however, we find still a negative cost effect for the 3rd and 4th moment of profit (i.e. skewness and kurtosis of profit). The age and experience of the farmer shows still a compensating effect on the risk proxies' cost effects, whereas the size of the farm, the degree of farm specialisation as well as off-farm income all seem to have a reinforcing effect on the risk proxies cost implications. With respect to the compliance weighted NVZ scheme cost ratios the estimates imply a negative effect of the risk proxies for the 1st and 4th moment (mean and kurtosis of profit). Here, only time shows a compensating effect on the risk proxies' cost effects, whereas again the size of the farm has a reinforcing effect on the risk proxies cost implications.

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 ESS 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. 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 NVZ and ESS models implying that farmers use the scheme income as a means to hedge against such risk. Further the results reveal, that the higher the expected upside profit variability (negative skewnee estimate), the lower the significance of risk and the probability of loss, hence, the lower the willingness/need to join management agreement type agri-env schemes to hedge against such risk. Based on these findings we formulate the following preliminary policy conclusions: (1) The farms' actual market/production risk has significant effects on the instruments' cost effectiveness. (2) Such risk leads to a lower cost effectiveness for the command and control type instrument, but a higher cost effectiveness for the management agreement type instrument. (3) Risk averse farmers who face uncertainty in their production income are more likely to comply with voluntary agri-environmental schemes as a means of risk management (to hedge against such risk effects). (4) To address such adverse risk effects for the NVZ instrument, the support of part-time farming but also the support of intensification/specialisation could be relevant. (5) To exploit the beneficial risk effects for the ESS instrument, again the support of part-time farming but also the support of intensification/specialisation could be relevant. (6) The level of education, knowledge dissemination and spillover effects matter with respect to the cost-effectiveness of the command and control type instrument.

Scheme Scale and Scope

The regression results show finally for the unweighted and compliance weighted NVZ scheme related cost ratios that the more utilised agricultural area (uaa) is under the NVZ scheme per farm, the lower the average costs per ha for the scheme (i.e. economies of scale with respect to scheme participation). Further, the more farm output is generated by compensation payments from the ESS program, the lower the costs per ha for the NVZ scheme which suggests economies of scope with respect to agri-environmental schemes' participation. The regression results show for the compliance weighted and unweighted ESS scheme related cost ratios that the more uaa is under the scheme per farm, the lower the average costs per ha for the ESS scheme (i.e. economies of scale with respect to scheme participation). The findings, however, do not confirm the cost savings with respect to multi-scheme participation found for the NVZ scheme. The strong empirical evidence for significant cost savings due to economies of scope with respect to both agri-environmental schemes 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. Based on these findings we formulate the following preliminary policy conclusions: (1) Economies of scale are the case for both instruments, i.e. cost savings and a higher cost-effectiveness can be reached by larger farms under the schemes. (2) Economies of scope (or joint production effects) are only confirmed for the command and control instrument. Hence, if a farm is already located in a an NVZ area, the implementation of the instrument will be more cost-effective if the farm also participates in the management agreement-type instrument. This could probably be explained by the resulting higher compliance rate for the NVZ instrument.

In summary: The cost-effectiveness of the ESS instrument is higher than the cost-effectiveness of the NVZ instrument for the unweighted case. However, this result changes if the focus is on the compliance weighted cost ratios where for the period 2006 to 2008 the mean cost per ha are more or less the same for the two instruments over the period considered. The results show further that the cost-effectiveness for the ESS and the NVZ schemes varies on a regional level as well as over time. 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 socioeconomic characteristics, management skills and attitudes, production focus, location, technologies, economic performance and risk. Finally, the empirical analysis revealed significant economies of scale and scope with respect to the management of agri-environmental schemes.

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. 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 scale of scheme participation/exposure 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.

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 the joint production of policy instruments can lead to cost savings through scope and 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).

VII) Conclusions

This analysis contributes to the agri-environmental policy relevant 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 for a command and control versus a management agreement type instrument. 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. By applying a three-stage estimation procedure we significantly contribute to the literature by improving on earlier empirical studies. To avoid small sample bias and non-robust results we use a satisfactorily large sample for the full NVZ and ESS schemes and a statistical resampling procedure to generate robust results. 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 data availability they have essential utility in providing benchmark figures for further schemes' revisions towards an increased instruments' efficiency. Consequently, the following policy implications should be outlined:

(1) To increase the cost-effectiveness of a command and control type instrument, knowledge dissemination and spillover effects via interest and peer-groups should be used.

(2) A management agreement-type instrument is more cost-effective for organic farms, part-time farmers and for farms located in less favoured areas (LFA).

(3) In terms of mitigating adverse risk effects on the instrument's cost-effectiveness, supporting the schemes' take-up by part-time farmers and specialised farmers would assist in achieving that outcome. The negative effects for the instruments' cost due to risk are significantly lower for part-time farmers and highly specialised farms.

(4) Compliance monitoring for management agreement-type instruments should focus on farms outside of LFA.

(5) The targeting of larger farms would lead to cost savings and a higher cost-effectiveness for both instruments.

(6) 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 administrative cost-effectiveness variability across space and sectors.

(7) 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.

(8) Incentive-compatible scheme design has to take into account also the individual risk faced by the farmer. The findings suggest that production and market risk have a significant influence on the inidvidual farmer's behaviour regarding participation and compliance with the instruments investigated. Considering these effects the instruments' cost-effectiveness could be increased e.g. by offering different compensation payments per option for farmers facing different degrees of risk.

(9) Informed (and quantified) analysis about recipients technological characteristics and economic performance is crucial for the instruments success. Economic performance and compliance is linked.

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Appendix

Table A1 - 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; > 50% of 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 A2 - Technological Variables and Risk Proxies for Farm Sample (2006 to 2008, 2286 observations)

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

Table A3 - Estimates Various Panel Regressions Nitrate Vulnerable Zones

Dependent Variable	Model 1 RE NVZ CE NVZ		Model 2 AR(1) NVZ CE NVZ		Model 1 RE NVZc CE NVZc		Model 2 AR(1) NVZc CE NVZc	
Independent Variables	*est*	*se* [5]	*est*	*se* [5]	*est*	*se* [5]	*est*	*se* [5]
time	9.35***	0.28	10.18***	0.34	30.77***	0.49	30.43***	0.52
ea01	-169.48***	2.49	-76.57***	2.69	69.46***	6.97	69.80***	10.09
ea02	-124.15***	2.57	-33.29***	2.71	102.06**	5.01	102.04***	5.08
ea03	-44.41***	2.74	42.93***	3.04	39.01***	4.82	39.18***	4.88
ea04	7.88***	2.99	103.81***	3.29	-46.68***	4.62	-47.29***	4.31
ea05	-89.65***	3.05	88.95***	3.58	-26.78***	4.62	-27.01***	4.67
ea07	-162.97***	3.07	-66.77***	3.39	-74.99***	4.17	-75.23***	4.23
Robust Type 1 ‘cereals’	-2.31***	0.51	-0.97*	0.67	-19.79**	9.45	-19.03**	9.64
Robust Type 2 ‘general cropping’	-1.98***	0.58	-1.12**	0.61	-16.65*	9.55	-16.48*	9.75
Robust Type 3 ‘horticulture’	5.60	5.14	2.86	6.14	-3.38	9.55	-4.38	9.75
Robust Type 4 ‘pigs’	5.21	5.41	4.91	6.58	-21.07**	10.22	-21.42**	10.46
Robust Type 5 ‘poultry’	8.54	5.06	6.89	6.72	-9.67	10.45	-10.12	10.67
Robust Type 6 ‘dairy’	2.19***	0.57	0.97*	0.63	-18.32	9.37	-17.91	9.51
Robust Type 7 ‘lfa grazing livestock’	2.75***	0.69	1.46**	0.73	-2.52	11.46	-1.51	11.69
Robust Type 8 ‘lowland grazing livestock’	2.98	5.12	3.28	6.11	-12.54	9.49	-13.06	9.69
Robust Type 9 ‘mixed’	5.56	5.16	5.12	6.12	-16.24*	9.52	-16.21*	9.73
technical efficiency [1]	-6.52	4.47	-7.89*	4.80	10.92	7.98	13.55	7.90
organic production	3.74**	1.99	3.72	2.75	-7.78*	4.27	-7.11*	4.31
total sales	-2.13e-06	1.91e-06	-2.31e-06	2.36e-06	3.97e-06	3.71e-06	4.65e-06	3.77e-06
farm size	-0.13	0.55	-0.48	0.65	-0.63	1.04	-0.41	1.05
subsidies	5.94e-05***	2.11e-05	7.92e-05***	2.51e-05	5.3e-05	3.93e-05	4.14e-05	4.02e-05
off-farm income	9.24e-05**	5.03e-05	3.81e-05	5.61e-05	-1.78e-05	8.94e-05	-2.26e-05	9.02e-05
share of hired labor	-13.56***	1.56	-12.76***	1.46	8.02***	2.53	6.46***	2.45
rental equivalent	-3.76***	1.26	-4.68***	1.17	-1.84	2.04	-0.16	1.96
debt to assets	1.76	2.19	0.71	2.04	-4.24	3.56	-3.41	3.44
tenancy ratio	-3.19***	0.85	-2.71***	0.77	-2.56*	1.39	-2.01*	1.30
ratio subsidies to gross margin	7.56***	2.46	5.20**	2.29	16.36***	3.97	14.08***	3.83
contracting	-2.05	2.74	-2.68	2.58	3.31	4.39	2.44	4.29
degree of specialisation	6.46***	2.28	6.22***	2.16	-0.37	3.71	-2.31	3.60
Altitude 2 – Most of Holding at 300m-600m [3]	2.85	3.63	4.17	4.63	10.97	7.25	11.48*	7.31
Altitude 3 – Most of Holding at >600m [3]	17.35***	5.72	18.31**	7.36	17.74	11.59	19.04*	11.71
Less Favoured Area 2 – All Land inside SDA [4]	-3.43	4.24	-1.41	5.48	-8.53	8.67	-9.78	8.79
Less Favoured Area 3 – All Land inside DA [4]	1.82	4.33	4.85	5.47	8.78	8.59	6.08	8.75
Less Favoured Area 4 –50%+ Land in LFA of which 50%+ in SDA [4]	-3.42	4.53	-0.34	5.81	-5.77	9.01	-5.28	9.24
Less Favoured Area 5 –50%+ Land in LFA of which 50%+ in DA [4]	-2.36	5.31	-1.26	6.89	-2.05	10.87	-3.39	11.09
Less Favoured Area 6 –<50% Land in LFA of which 50%+ in SDA [4]	-2.22	10.98	-12.57	12.92	32.95*	19.62	21.34	20.49
Less Favoured Area 7 –<50% Land in LFA of which 50%+ in DA [4]	16.82***	7.01	20.58***	8.05	-5.61	13.81	-5.67	13.99

1 : Estimates obtained by Generalized Transformation Frontier; 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 A3 cont.

Independent Variables	*est*	*se* [5]	*est*	*se* [5]	*est*	*se* [5]	*est*	*se* [5]
Age	-0.11**	0.05	-0.12***	0.04	0.23*	0.09	0.24**	0.09
Education	-1.54***	0.46	-2.02***	0.43	0.97	0.75	-8.63e-03	0.72
Risk Proxy 1 – Expected Profit (Mean) [2]	45.81*	20.97	31.43*	20.47	-105.12**	40.88	-89.91**	39.47
Risk Proxy 2 – Profit Variability (Variance) [2]	639.78***	182.31	432.68**	172.74	1271.89***	294.32	981.66***	286.48
Risk Proxy 3 – Profit Asymmetry (Skewness) [2]	-30.69	62.55	131.03**	62.33	905.95	105.55	837.67	103.01
Risk Proxy 4 – Profit Peakedness (Kurtosis) [2]	239.18***	81.14	132.11*	82.28	-1025.77***	139.39	-929.76***	137.04
Risk Proxy 5 – Expected Profit * Age [2]	-0.31	0.35	-0.12	0.32	0.34	0.56	0.19	0.54
Risk Proxy 6 – Variability of Profit * Age [2]	0.07	2.45	0.96	2.29	-3.31	3.95	-1.66	3.83
Risk Proxy 7 – Expected Profit * Education [2]	-6.71**	3.17	-4.58*	2.94	-0.72	5.05	-0.41	4.92
Risk Proxy 8 – Variability of Profit * Education [2]	26.59	18.73	-31.53**	17.01	4.14	29.99	17.93	28.80
Risk Proxy 9 – Expected Profit * Time [2]	-3.12**	1.46	-3.02**	1.34	4.50**	2.32	3.61*	2.24
Risk Proxy 10 – Variability of Profit * Time [2]	54.73***	10.27	29.43***	10.66	-94.71***	16.94	-79.09***	17.12
Risk Proxy 11 – Expected Profit * Specialisation [2]	-7.16	14.45	-2.81	13.31	12.87	23.11	23.99	22.32
Risk Proxy 12 – Variability of Profit * Specialisation [2]	-151.62*	93.51	-167.48**	88.59	-87.65	151.52	-28.25	147.62
Risk Proxy 13 – Expected Profit * Off-Farm Income [2]	-3.39e-04	3.36e-04	-2.34e-04	3.12e-04	5.32e-04	5.34e-05	3.75e-04	5.19e-04
Risk Proxy 14 – Variability of Profit * Off-Farm Inc. [2]	-3.51e-03**	1.81e-03	-3.75e-03**	1.87e-03	0.005*	0.003	0.004	0.003
Risk Proxy 15 – Expected Profit * Farm Size [2]	6.81**	3.02	5.29**	2.76	16.63***	4.73	14.88***	4.61
Risk Proxy 16 – Variability of Profit * Farm Size [2]	35.85**	18.09	48.83***	19.04	5.93	32.91	0.21	32.26
Area under Nitrate Vulnerable Scheme	-0.05**	0.02	-0.07**	0.03	-0.22***	0.05	-0.22***	0.05
Income due to Environmental Stewardship Scheme	-6.97e-04***	1.02e-04	-7.35e-04***	1.16e-04	-0.001***	1.78e-04	-0.001***	1.84e-04
Constant	212.95***	12.11	124.28***	14.41	-57.58	13.87	-52.27***	14.02
R-Square Within	0.2710		0.2766		0.4609		0.4597	
R-Square Between	0.9498		0.9454		0.8046		0.8052	
R-Square Overall	0.7834		0.7807		0.6861		0.6852	
Wald Chi2(52) / Prob > Chi2	19806.78	(0.000)	12035.27	(0.000)	10090.53	(0.000)	9018.23	(0.000)
Number of Observations (n)	5534		5534		5534		5534	
Number of Groups (n)	1705		1705		1705		1705	
Observations per Group (min/avg/max)	1/3.2/9		1/3.2/9		1/3.2/9		1/3.2/9	
rho_ar	---		0.414		---		0.241	
modified DW-test	---		1.259		---		1.578	
Baltagi-Wu-LBI	---		1.654		---		2.062	
Bootstrap Replications	10,000		10,000		10,000		10,000	

1 : Estimates obtained by Generalized Transformation Frontier; 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 A4 - Estimates Various Panel Regressions Environmental Stewardship Scheme

Dependent Variable	Model 1 RE ESS CE ESS		Model 2 AR(1) ESS CE ESS		Model 1 RE ESSc CE ESSc		Model 2 AR(1) ESSc CE ESSc	
Independent Variables	*est*	*se* [5]	*est*	*se* [5]	*est*	*se* [5]	*est*	*se* [5]
time	35.52***	0.44	35.51***	0.45	72.83***	1.99	72.69***	2.02
gor01	33.59***	1.98	33.32***	2.07	9.76	8.99	7.49	10.37
gor02	49.43***	1.15	48.72***	1.22	12.27**	5.21	5.64	6.27
gor05	35.22***	1.05	34.72**	1.11	11.08***	4.74	5.75	5.79
gor06	57.15***	0.98	56.96***	1.04	31.83***	4.45	28.26***	5.38
gor08	77.61***	1.13	77.88***	1.19	254.18***	5.11	259.24***	6.06
Robust Type 1 ‘cereals’	4.08	3.01	4.05	3.22	21.92*	13.01	24.59	16.69
Robust Type 2 ‘general cropping’	-5.02*	3.08	-5.01*	3.02	-27.36**	13.91	-29.91*	17.06
Robust Type 3 ‘horticulture’	7.07**	3.59	6.84*	3.82	35.66**	16.29	33.78*	19.69
Robust Type 4 ‘pigs’	2.57***	0.41	2.43***	0.44	23.12	18.72	24.37	23.35
Robust Type 5 ‘poultry’	5.91	4.19	5.77	4.39	22.23	18.97	22.66	22.05
Robust Type 6 ‘dairy’	-3.86**	1.94	-3.81***	0.35	-24.64*	13.31	-26.95*	16.32
Robust Type 7 ‘lfa grazing livestock’	3.54	3.66	3.42	3.89	-28.42***	6.55	-29.89***	2.05
Robust Type 8 ‘lowland grazing livestock’	4.88	3.91	4.79	3.92	23.98*	13.63	25.69*	16.07
Robust Type 9 ‘mixed’	4.85*	2.99	4.76*	3.01	25.59*	13.56	27.14*	16.71
technical efficiency [1]	2.35***	0.26	0.58*	0.25	7.91***	1.16	4.24***	1.91
organic production	-0.96***	0.18	-0.96***	0.11	-8.08*	4.90	-8.21	5.56
total sales	-1.04e-06	1.28e-06	-1.11e-06	1.36e-06	-5.13e-06	5.81e-06	-6.51e-06	6.94e-06
farm size	0.25	0.31	0.27	0.33	1.67	1.42	2.18	1.64
subsidies	1.30e-07	7.86e-06	3.99e-07	8.33e-06	-1.37e-05	3.56e-06	-8.90e-06	4.26e-05
off-farm income	-1.11e-05***	2.10e-06	-1.31e-05***	2.11e-06	-3.84e-05***	9.04e-06	-7.04e-05	1.05e-04
share of hired labor	0.85	0.86	-0.98	0.88	-8.34**	3.92	-9.84**	3.93
rental equivalent	3.07***	0.74	3.17***	0.75	10.49**	3.33	10.34***	3.28
debt to assets	-3.78***	1.22	-3.77***	1.24	-16.42***	5.53	-15.68***	5.46
tenancy ratio	-0.52	0.43	-0.56	0.43	0.09	1.95	-0.51	1.86
ratio subsidies to gross margin	-2.26*	1.37	-2.23*	1.30	-15.02**	6.21	-10.95*	6.09
contracting	0.82	1.76	0.86	1.78	5.27	7.96	4.25	7.85
degree of specialisation	1.61***	0.21	1.86*	1.03	1.25***	0.55	3.74***	0.56
Altitude 2 – Most of Holding at 300m-600m [3]	-0.29***	0.11	-0.54***	0.21	-2.15	9.05	-2.77	11.38
Altitude 3 – Most of Holding at >600m [3]	4.38	4.99	4.58	5.39	12.56	22.59	14.82	29.12
Less Favoured Area 2 – All Land inside SDA [4]	-4.43*	2.73	-2.72***	0.29	-5.71***	1.39	-5.49***	1.71
Less Favoured Area 3 – All Land inside DA [4]	-1.74	3.19	-1.61	3.38	-8.56***	1.44	-8.13***	1.39
Less Favoured Area 4 –50%+ Land in LFA of which 50%+ in SDA [4]	0.65	2.95	0.68	3.15	-1.75	13.33	-1.66	16.61
Less Favoured Area 5 –50%+ Land in LFA of which 50%+ in DA [4]	4.54	3.33	4.84	3.55	3.41	15.09	4.72	18.54
Less Favoured Area 6 –<50% Land in LFA of which 50%+ in SDA [4]	-0.68	8.67	-0.52	8.89	-2.55	39.25	-0.75	43.18
Less Favoured Area 7 –<50% Land in LFA of which 50%+ in DA [4]	-1.78	3.11	-2.10	3.23	-6.14	14.03	-9.21	16.14

1 : Estimates obtained by Generalized Transformation Frontier; 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 A4 cont.

Independent Variables	*est*	*se* [5]	*est*	*se* [5]	*est*	*se* [5]	*est*	*se* [5]
Age	0.07**	0.03	0.07***	0.02	0.22**	0.11	0.21**	0.09
Education	.023	0.31	0.29	0.31	0.41	1.36	1.07	1.33
Risk Proxy 1 – Expected Profit (Mean) [2]	-1.39***	0.49	-2.65***	0.41	72.57	185.07	16.57	179.92
Risk Proxy 2 – Profit Variability (Variance) [2]	247.79	222.80	282.12	226.70	890.04	1008.45	999.16	1013.52
Risk Proxy 3 – Profit Asymmetry (Skewness) [2]	-78.53**	35.33	-71.92**	36.19	-387.53***	159.91	-282.78**	166.03
Risk Proxy 4 – Profit Peakedness (Kurtosis) [2]	-99.02**	49.32	-99.69**	50.59	-600.668***	223.25	-646.01***	229.66
Risk Proxy 5 – Expected Profit * Age [2]	-0.51*	0.28	-0.55**	0.21	-2.67**	1.29	-3.33***	1.26
Risk Proxy 6 – Variability of Profit * Age [2]	-1.31	1.71	-1.41	1.73	1.95	7.73	2.06	7.59
Risk Proxy 7 – Expected Profit * Education [2]	2.85	3.51	2.92	3.54	1.55	15.84	1.42	15.28
Risk Proxy 8 – Variability of Profit * Education [2]	-9.39	16.28	-14.61	16.52	-59.36	73.71	-88.29	72.53
Risk Proxy 9 – Expected Profit * Time [2]	-0.06	3.86	0.71	3.92	-5.92	17.49	3.75	17.31
Risk Proxy 10 – Variability of Profit * Time [2]	-11.26	21.76	-12.02	22.14	-33.11	98.49	-26.21	99.51
Risk Proxy 11 – Expected Profit * Specialisation [2]	6.15	11.25	6.87	11.38	89.79*	50.94	105.66**	49.61
Risk Proxy 12 – Variability of Profit * Specialisation [2]	13.65	63.77	5.62	64.83	97.01	288.63	80.67	289.11
Risk Proxy 13 – Expected Profit * Off-Farm Income [2]	3.17e-04**	1.61e-04	3.43e-04**	1.62e-04	1.22e-03*	7.25e-04	1.69e-03***	7.06e-04
Risk Proxy 14 – Variability of Profit * Off-Farm Inc. [2]	1.65e-04	5.94e-04	1.73e-04	6.11e-04	2.49e-03	2.69e-03	2.87e-03	2.86e-03
Risk Proxy 15 – Expected Profit * Farm Size [2]	-3.91*	2.23	-3.66*	2.21	16.31*	10.08	13.29	9.66
Risk Proxy 16 – Variability of Profit * Farm Size [2]	-3.36	11.89	-3.29	12.27	-58.03	53.83	-54.41	56.74
Area under Nitrate Vulnerable Scheme	3.87e-03	0.01	6.09e-03	0.01	0.01	0.06	0.05	0.07
Income due to Environmental Stewardship Scheme	-0.96***	0.11	-0.95***	0.12	-7.81e-03***	1.57e-04	-2.39e-03***	1.91e-04
Constant	-243.71***	8.23	-243.78***	-28.01	-537.79***	37.27	-542.08***	44.22
R-Square Within	0.9196		0.9201		0.7035		0.7072	
R-Square Between	0.9687		0.9692		0.9495		0.9498	
R-Square Overall	0.9495		0.9494		0.8900		0.8888	
Wald Chi2(52) / Prob > Chi2	16882.82	(0.000)	15806.82	(0.000)	7258.15	(0.000)	5647.56	(0.000)
Number of Observations (n)	953		953		953		953	
Number of Groups (n)	570		570		570		570	
Observations per Group (min/avg/max)	1/1.7/3		1/1.7/3		1/1.7/3		1/1.7/3	
rho_ar	---		0.139		---		0.469	
modified DW-test	---		1.784		---		1.177	
Baltagi-Wu-LBI	---		2.609		---		2.208	
Bootstrap Replications	10,000		10,000		10,000		10,000	

1 : Estimates obtained by Generalized Transformation Frontier; 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.

[i] However, it has to be stressed that reputational costs may lead to discontinuouities.

[ii] 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).

[iii] 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.

[iv] Data on compliance rates per region and year was obtained from Natural England (ESS) and the Environment Agency (EA). These rates are based on the share of inspection visits with a positive (complying) finding out of all inspection visits in a given region and year.

[v] The majority of farms are in the sample for 1 to 2 years. We tested for an alternative random effects specification which proved to be not significant. Hence, we opted for a pooled cross-section specification of the model.

[vi] 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 random-effects regression results. We further run separate regressions for compensatory payments and scheme transaction costs with respect to the ESS scheme. 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.

[vii] 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.