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ENVIRONMENTAL EFFICIENCY OF SMALL FARMS IN SELECTED EU NMS [1]

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Abstract

The objective of this paper is to investigate the relationship between the environmental efficiency and farm commercialisation in selected EU NMS (Bulgaria, Romania and Poland). Using a cross-section of agricultural households, environmental technical efficiency scores are calculated using hyperbolic distance function approach. The results indicate there is a negative relation between the increase in commercialisation of small farms and the production of negative externalities, like nitrogen surplus.

Keywords: distance function, nitrogen surplus, market integration, stochastic frontier analysis

Introduction

While the Common Agricultural Policy (CAP) of the EU recognises that food production remains the main function of agriculture, pillar two of the CAP explicitly promotes the production of environmental outputs, like biodiversity and landscape amenities. In the New Member States, subsistence agriculture became more widespread during the transition period which was characterised by economic restructuring and a resulting decrease in non-agricultural employment level. The restitution of ownership to the pre-communist land owners and the increased level of unemployment led to an increase in the number of subsistence/ semi-subsistence farmers, initially using agriculture as a buffer against unemployment. These subsistence and semi-subsistence units coexist with commercial agriculture. However, despite the progress with economic restructuring and reappearance of economic growth subsistence and semi-subsistence structures remain and appear to be quite resilient, perhaps due to subsistence poverty-trap phenomenon and/ or to the lifestyle preference.

Given the apparent resilience of subsistence agriculture, and the policy goal of rapid commercialisation an assessment of the comparative provision of environmental outputs is useful. The environmental outputs can be negative externality (e.g. nitrogen surplus) or positive externality (e.g. crop diversity). Several studies give evidence of environmental benefits of small semi-subsistence farms in comparison to intensive specialised business operations. (Brush *et al.*, 1992;Van Dusen *et al.*, 2005;Omer *et al.*, 2007)

The decline in the subsistence level in NMSs could be achieved by policies promoting structural change through an increase in their level of market integration or by encouraging them to give up agriculture altogether. A support package of measures based on European Commission regulations 1698/2005 is being developed to support semi-subsistence farmers undergoing restructuring. It is conditional on a business plan and it is under a form of a flat payment per year (European Council, 2005). However, very little research has been done on the environmental effects of such a structural change. This research is aimed at filling this gap.

The objective of this paper is to investigate the relationship between the environmental efficiency and farm commercialisation. This will inform the debate on whether EU and national policies need support semi-subsistence farms in order to compensate them for the delivery of environmental public goods.

Literature review

The role of agriculture in the supply of non-commodity outputs (NCO) has been recognised given the existence of jointness in the production between NCOs and commodity outputs, and the existence of market failure in the provision of NCOs (OECD, 2005a). The term non-commodity output defines a good that has a public good or externalities characteristic e.g., environmental services, food security, land conservation, pollution (OECD, 2005b). For the purpose of this paper, we will mostly concentrate on the negative externalities that arise from agriculture and refer to them using the term environmental output.

The amount of marketable[2] and environmental output supplied depends on farms heterogeneity (Bontems *et al.*, 2004) which is given by soil, climate, farm location and the level of intensification (Le Cotty *et al.*, 2008), or type of farming practice (Hodge, 2008). For example, crop selection, crop rotation and tillage contribute to the "provision" of negative externality outputs, i.e. soil erosion, nutrient run-off.

As mentioned, this paper focuses on identifying the change in environmental outputs due to the transition from subsistence to commercial farming. There is no agreed definition or a measure of subsistence. A subsistence household is considered as an agricultural household that consumes its agricultural production entirely. At the opposite end, commercial households are those selling all their agricultural output. However, in reality it is more likely to encounter households that are either subsistence-orientated (that sell less than 50% of their output) or commercial-orientated households (that sell more than 50% of their output).

The interest in studying subsistence agriculture is motivated by governments' desire to reduce to number of households[3] that are practising this type of agriculture. Although it has been highlighted that subsistence agriculture has an important role in improving the low-income households' diet during transition times, subsistence-orientated households are considered to be an "impediment to economic growth" and they have a low responsiveness to government policies (Heidhues *et al.*, 2003).

The reasons behind the level of market integration of semi-subsistence households have been given a substantial attention in the literature since it affects the aggregate market supply of agricultural output (Renkow, 1990). Toquero *et al.* (1975) found that the portion of output which is sold is mainly influenced by the output yield. Their policy implications suggested that targeting technology improvement would be more successful in increasing the subsistence household/ farms marketable output than those offering price support.

Similar policy implications were suggested by Rios *et al.* (2008) who tested the direction of causality between the productivity and market integration for households in three countries: Tanzania, Vietnam and Guatemala. They found that for the countries analysed there was a positive correlation between the agricultural productivity and the commercial orientation of the households.

Unfortunately, apart from marketable outputs and positive externalities[4], agriculture supplies also negative externalities. In all types of production processes, there is no complete transformation of inputs into outputs, so there is always a residual or by-product (Ebert *et al.*, 2007). The production process of any agricultural household involves the use of market inputs (e.g. pesticides and fertilisers), land, family and hired labour, and capital to obtain outputs. Similarly to any production process, agricultural production may lead to some by-products which are considered negative externalities like waste[5] (e.g. nutrient run-offs) and pollution (e.g. water contamination).

The environmental impacts, usually associated with agricultural production, are on soil and water quality, air quality, biodiversity, wildlife habitats and landscape amenities. The positive and/or negative externalities of agriculture are linked to the agricultural practices through the level of agricultural output produced, technology used, and the amount and mix of chemicals (Kelly *et al.*, 1996;OECD, 1998). For example, different input combinations and the allocation of land between marketable outputs affect the biodiversity, and nutrient and pesticides runoffs (Lankoski *et al.*, 2003).

[2] The marketable output from agricultural activity refers to all agricultural products for which a market exists.
[3] In Romania alone there are around 3.9 million agricultural households, and 1.6 million own less than one ha (European Commission, 2002).
[4] For example, biodiversity.
[5] Waste is defined here as the surplus of inputs that was not transformed into outputs through the production process.

However, a change in farming practices might lead to loss of farm income or the need for investment in new technology. Kelly *et al.* (1996) and Bailey *et al.*(1999) investigated the tradeoffs between farm income and environmental performance of different cropping systems. The study of Kelly *et al.* (1996) shows that no-till rotation systems lead to the greatest net returns in the long run with the lowest nitrogen loss. Also, the conventional tillage system is preferred to the reduced-tillage system because it uses less chemical fertiliser and herbicides.

Given the popularity of the agri-environmental schemes to promote good farming practices, Havlik (2005) has simulated the impact on the environmental outputs when direct payments are completely decoupled for beef farmers in France and the Czech Republic. When the farmers are part of an agri-environmental scheme, they receive a payment for the provision of environmental output which aims at ensuring that their supply will reach the social optimum. The question that arises in this case is whatever the NCOs could the NCO be provided cheaper by other activity than jointly produced NCOs and agricultural output? (Le Cotty *et al.*, 2008)

One way to reduce the level of negative externalities produced by small households who may not take part into an agri-environmental scheme will be either to force them out of agriculture or to provide opportunities for off-farm income in order to reduce their on-farm labour hours. Shively *et al.* (2006) show that the existence of off-farm employment opportunities can reduce the deforestation level and erosion damage of using improper farm practices. In the latter case, it is argued that the interaction between two agricultural systems (in upstream and in downstream) on the labour market leads to a reduction in the soil erosion generated by upstream farms which has an impact on productivity gains of downstream farms.

It can be argued that the causality between environment and agricultural production goes both ways. Rahman and Hasan (2008) show, using data on wheat producers from Bangladesh, that land type, soil quality and delay in sowing have an important effect on productivity and their omission from inefficiency estimations may lead to an upward bias.

When investigating negative externalities, there is a question: who should pay for the damage. Applying the ‘polluter pays principle’ is difficult in agriculture, especially when the use of contaminants, i.e. chemical fertilisers and pesticides, leads to non-source pollution. The problem is exacerbated in the case of large land fragmentation; one can only acknowledge the contamination of ground water with nitrates in an area. Retracing the source it is almost an impossible task.

Internalising the cost of pollution involves setting penalty taxes or rates by the government. It is also difficult to set the correct price for environmental goods given there is no market for it. Most of the studies in pollution modelling are using shadow prices based on abatement cost or the level of tax.[6] To solve this problem, Fare *et al.* (1993) developed a new approach to generate shadow price for undesirable outputs, i.e. pollution or ‘bads’, by estimating output distance functions as frontiers.

One alternative approach for modelling “bad” outputs takes into account the material-balance condition: ‘‘what goes in must come out’’(Coelli *et al.*, 2007). Based on this condition, Coelli *et al.* (2007) proposes a new measure for environmental efficiency by minimising the quantity of nutrients associated with producing a certain amount of agricultural output, e.g. minimising the nutrient surplus (nitrogen and phosphorus) in livestock production.

There are several studies that either develop a new efficiency measurement tools which take into account both desirable and undesirable outputs (Färe *et al.*, 1989;Färe *et al.*, 1998;Fernandez *et al.*, 2002;Färe *et al.*, 2004), or propose an environmental efficiency measure (Färe *et al.*, 1996;Reinhard, 1999;Coelli *et al.*, 2007).

Estimating the environmental efficiency (EE) is a useful tool in assessing the environmental impact of an economic activity with several unintended outputs. Most of the studies use distance

[6] For agriculture, as a price of environmental output, the payment received in agri-environmental schemes could be used. (Le Cotty *et al.*, 2008)

function approach which has the advantage of not requiring prices for outputs (Färe *et al.*, 1996;Reinhard *et al.*, 1999;Färe *et al.*, 2004;Aiken, 2006). For example, Reinhard *et al.* (1999) and Fernandez *et al.* (2002) have computed the EE scores for Dutch dairy farms using as undesired output the nitrogen surplus. It is a proxy for the environmental damage caused by nitrogen run-off in agriculture.

Another approach to assess the negative externalities from agriculture involves estimating the impact of the contamination-causing inputs on EE or technical efficiency (TE) using stochastic frontier approach. Reinhard *et al.*(2002) investigate the factors that could explain the variation in environmental efficiency between Dutch dairy farms. As expected, nitrogen in inputs is negatively related to the EE. Hadri *et al.* (1999) identified a negative relationship between technical inefficiency and farm size, and the use of fertilisers and pesticides.

Not only 'bad' outputs can affect the farm efficiency. Areal *et al.*(2009) discovered that farm efficiency scores change when taking into account the provision of positive externality outputs. Biodiversity is considered a positive externality output of agriculture and it is linked to the composition of commodity output and farming practices (OECD, 2001). One of the components of biodiversity – agricultural diversity[7] was given special attention in the literature especially in relation to small farms. Several studies identified the contribution of small farms to the preservation of agricultural diversity (Brush *et al.*, 1992;Birol *et al.*, 2004;Van Dusen *et al.*, 2005;Di Falco *et al.*, 2009) but we were unable to find any study focusing on the negative externality output provided by small farms.

Methodology

As mentioned before, the focus of this paper is the link between subsistence and commercial behaviour, on the one hand, and the possible environmental outputs that result from the different degrees of market integration of agricultural households. The main assumption is that changing the degree of market integration affects farm practice and results in different environmental effects.

The empirical analysis consists of the following steps: (i) computation of environmental efficiency; (ii) estimation of the effects of market integration, farming practices and other relevant variables on the environmental efficiency scores.

Since there is no price information about the environmental output[8], distance function approach is preferred to characterise the multi-output technology used by the agricultural household. This approach is also useful since it is not certain that the behaviour of subsistence orientated households can be considered as either cost minimising or revenue maximising (Coelli *et al.*, 2005).

If we denote $y \in \Re_+^m$ the vector of m agricultural products (marketable output), $z \in \Re_+^j$ represents the vector of j environmental outputs and $x \in \Re_+^n$ the vector of inputs, then the household's technology set are:

$$T = \{(x, y, z) : x \text{ can produce } (y, z)\} \qquad (1)$$

Since it is not feasible to reduce the production of environmental outputs without also reducing the production of intended outputs (i.e. agricultural products), we assume that the technology is weakly disposable in outputs, i.e. if $(x, y, z) \in T$ $\mathbf{0 < \theta < 1 \text{ then } (x, y/\theta, \theta z) \in T}$.

[7] It reflects the diversity within and among species found in crops and domesticated livestock systems (Di Falco *et al.*, 2008)
[8] As mention above, by environmental output it is meant nitrogen surplus as a negative externality.

To compute the environmental efficiency, the hyperbolic distance function approach, as presented in Cuesta *et al.*(2009) is applied. This approach has the benefit of allowing agricultural products and negative externality "to vary in the same proportion but in opposite directions" (p. 2233).

The technology of the agricultural household is represented by a hyperbolic distance function which describes the maximum expansion of agricultural products vector (*y*) and equiproportionate contraction of environmental vector (*z*) when the input vector (*x*) is fixed (Cuesta *et al.*, 2009: 2234):

$$\boldsymbol{D_H(x,y,z) = \inf_\theta \left\{ \theta > 0 : \left(x, \frac{y}{\theta}, \theta z \right) \in T \right\}} \qquad (2)$$
$$\boldsymbol{(x,y,z) \in T \Leftrightarrow 0 < D(x,y,z) \leq 1}$$

By treating the marketable and environmental outputs asymmetrically, one provides an environmental friendly characterisation of production technology (Cuesta *et al.*, 2009). If $D_H = 1$, then it could be said that the agricultural household is using the most environmental friendly farming practices.

In the second step, it is assumed that environmental efficiency of the agricultural household is influenced by the decision to consume or sale its output. Thus, the functional relationship between environmental efficiency and market integration, household and farm characteristics will be tested.

The existence of the following function is considered:

$$EE = g(mk, \Psi_{HH}) \qquad (3)$$

Where Mk = market participation index[9];

Ψ_{HH} = vector of farm and household characteristics, e.g. age and education of the head of household, size of the household, main employment of the household head, existence of off-farm income.

Data

In this paper we use primary data on agricultural households from a survey carried out within EU FP6 SCARLED project. The sample consists of a cross-section of 455 households from Bulgaria, Poland and Romania and their agricultural activity in 2006.

To avoid the problem of multicollinearity, for the estimation of the hyperbolic distance function, only three outputs and four inputs will be used. The inputs have been aggregated in four categories: land (ha), labour (hours), manure used (kg) and other inputs (PPP currency). Two marketable outputs, e.g. crop output and animal output, are aggregated as implicit quantity index using prices expressed in PPP. The environmental output used in the analysis is nitrogen surplus calculated using a farm-gate definition and it is measured in kg (Brouwer, 1998).

The descriptive statistics of the all variables used in the analysis are summarised in Table 1.

[9] The market participation index will be calculated using $Sales\ Index_i = \frac{\sum_{j=1}^{J} Total\ sales_{ij}}{\sum_{j=1}^{J} Total\ production_{ij}}$

Table 1 Descriptive statistics of the sample

Variable[10]	Mean	Std. Dev.	Min	Max
y1 Crop output	2.123	3.745	.0209266	38.11501
y2 Animal output	2.301	3.607	.0031728	29.24296
z Nitrogen surplus	2.802	5.382	.0002801	39.72583
x1 Land	1.933	2.942	.0018254	29.31581
x2 Labour	1.339	.972	.0180196	6.193049
x3 Manure	.418	1.001	0	6.055902
x4 Other variables	2.597	4.307	8.36e-06	36.28432
Manure dummy (dx3)[11]	1=26.59% 0=73.41%			

For the second stage of the analysis, different farm and household characteristics are used to determine their influence on the environmental efficiency. The variables were selected based on the most commonly used in previous studies (Chavas *et al.*, 2005;Latruffe *et al.*, 2008).

Table 2 Descriptive statistics of variables used in second stage estimation

Variable	Mean	Std. Dev.	Min	Max
Market integration	.364	.268	0	1
Age of household head	55.56	13.437	18	89
Gender of household head	Male= 85.05% Female= 14.95%			
Main employment area of household head	Farm work on own land=23.57% Wage job= 29.74% Other = 7.27% Pensioner = 39.43%			
Using hired labour	Yes = 13.41% No = 86.59%			
How did you farm your land?	Mainly agricultural machinery = 74.01% Mixed = 12.78% Mainly manually = 13.22%			
Education of the household head	No schooling = 1.32% Primary & Middle school = 51.87% High school = 41.10% University = 5.71%			
Existence of wage income in the household	Yes = 59.47% No = 40.53%			

Results

Estimation of environmental efficiency

The first step consists of a parametric estimation of hyperbolic distance function using stochastic frontier approach since it separates environmental inefficiency from random noise that cannot be controlled by the agricultural household. For this purpose we have to choose a flexible functional form. The most used functional form in the literature is the translog (Lovell *et al.*, 1990;Reinhard, 1999;Coelli *et al.*, 2000;Nehring *et al.*, 2003;Huang *et al.*, 2007;Cuesta *et al.*, 2009).

[10] All inputs and outputs were divided by their geometric mean prior to the analysis.
[11] Since there are households that do not used manure and a translog function form will be used in the analysis, we follow the method proposed by Battese (1997) and replace $x_3^i = \max(x_3^i, dx_3^i)$. dx_3 is a dummy variable which takes the value of one if the quantity of manure is zero.

The benefits of using distance function approach are that it does not require aggregation, prices or behavioural assumption. The main difficulty in econometrically estimating the distance function lies in the dependent variable – one does not observe it. To solve this problem, one utilises the property that the hyperbolic distance function is almost homogeneous of degree (0, 1, -1, and 1):

$$D(X, \lambda Y, \lambda^{-1} Z) = \lambda D(X, Y, Z) \quad \text{for any } \lambda > 0 \qquad (4)$$

The translog hyperbolic distance function with two marketable, one environmental output and four inputs is described by:

$$lnD_H = \alpha_0 + \sum_{i=1}^{2} \alpha_i lny_i + \alpha_3 lnz + \sum_{i=2}^{4} \beta_i lnx_i \ + \frac{1}{2} \sum_{i=1}^{2} \sum_{j=1}^{2} \alpha_{ij} lny_i lny_j + \frac{1}{2} lnz * lnz + \frac{1}{2} \sum_{i=1}^{4} \sum_{j=1}^{4} \beta_{ij}\, lnx_i \ \ lnx_j \ + \sum_{i=1}^{2} \sum_{j=1}^{4} \delta_{ij}\, lny_i lnx_j \ + \sum_{i=1}^{2} lny_i lnz + \sum_{i=1}^{4} lnz lnx_i + \sum zerodummies + \sum \text{country dummies} + \varepsilon_i \qquad (5)$$

We can arbitrary choose one of the marketable outputs to impose the almost homogeneity condition so that: $\lambda = \frac{1}{Y_1}$ and we obtain:

$$-lny_1 = \alpha_0 + \sum_{i=1}^{4} \beta_i lnx_i + \alpha_2 lny_2^* + \alpha_3 lnz^* + \frac{1}{2} \sum_{i=1}^{4} \sum_{j=1}^{4} \beta_{ij} lnx_i lnx_j + \frac{1}{2} \alpha_{22} lny_2^* lny_2^* + \frac{1}{2} \alpha_{33} lnz^* lnz^* + \sum_{j=1}^{4} \delta_{2j}\, lnx_i lny_2^* + \sum_{j=1}^{4} \delta_{3j}\, lnx_i lnz^* \ + \sum zerodummies + \sum \text{country dummies} + u_i + v_i \qquad (6)$$

Where y_1 represents crop aggregated output and $y^*=y_2/y_1$ and $z^*=z^*y_1$;

$u_i \sim N(0, \sigma_u^2)$ represents the one-sided inefficiency and $v_i \sim N(0, \sigma_v^2)$ is the standard error term.

The estimated parameters of the translog using MLE are presented in Table 3. The Likelihood ratio test and the lambda value greater than one (λ=1.406) confirm the existence of inefficiency. Also, the extent of total variation ($\sigma^2 = \sigma_u^2 + \sigma_v^2$) due to differences in environmental efficiency is 66% (gamma value) which makes stochastic frontier a more appropriate estimation method than OLS. High gamma value implies that a high proportion of the differences between farmers' observed output and the maximum possible output are due to farmers' practices and behaviour rather than random variation.

Table 3 MLE estimation of the hyperbolic distance function

Variable	Coefficient	Std. Err.
Log(y2)	-0.254***	0.017
Log(z)	0.356***	0.019
Log(x1)	0.034	0.027
Log(x2)	0.065**	0.029
log(x3)	0.047	0.037
log(x4)	0.027	0.024
log(x4)*log(x4)	0.077***	0.016
log(y2)*log(y2)	-0.039***	0.012
log(y2)*log(z)	0.022***	0.007
log(z)*log(z)	0.060***	0.009
log(y2)*log(x2)	-0.041**	0.018
log(z)*log(x2)	-0.008	0.011
log(z)*log(x4)	-0.063***	0.013

dx3	-0.184***	0.049
_cons	0.511***	0.057
/lnsig2v	-2.137	0.156
/lnsig2u	-1.448	0.235
sigma_v	0.344	0.027
sigma_u	0.485	0.057
sigma2	0.353	0.043
Lambda= sigma_u/ sigma_v	1.411	0.079
Gamma	0.666	
Number of obs = 455 Wald chi2(14) = 2902.44 Prob > chi2 = 0.0000 Log likelihood = -279.91701		

Note: ***, **, * ==> Significance at 1%, 5%, 10% level.

With a full translog specification only 43% of the parameters are significant. In this case, we test if other specifications for the functional form perform better, including a scaled down translog specification. The scaled down translog includes only those interaction terms and dummies[12] that were statistically significant at 10% level in the estimation of the full translog specification. From the results in Table 4, we may conclude that scaled down translog is the most appropriate specification of the functional form.

Table 4 Tests for alternative specifications of the functional form

Model	Null Hypothesis	Log likelihood	Chi2 critical value	Decision
Full translog		-270.19861		
Cobb-Douglas		-320.67395	100.95	rejected
Simplified translog	All $\delta_{ij} = 0$	-288.96565	37.53	rejected
Scaled down translog		-279.91701	19.44	accepted

For the overall sample, the average environmental technical efficiency of agricultural households is 0.714. Agricultural household can increase agricultural outputs by 40% (=1/0.714) and at the same time reduce the nitrogen surplus by 28.5% (=1-0.714). The results are summarised in Table 5 and the frequency distribution of environmental technical efficiency is plotted in Figure 1. On average, Bulgarian households are less environmentally technical efficient compared with the other two countries.

Table 5 Environmental technical efficiency by country

Country	Obs	Mean	Std. Dev.	Min	Max
Bulgaria	120	.697	.153	.183	.910
Poland	114	.715	.111	.323	.917
Romania	221	.722	.083	.431	.918
Sample	455	.714	.112		

[12] Country dummies were not statistically significant at 10% level.

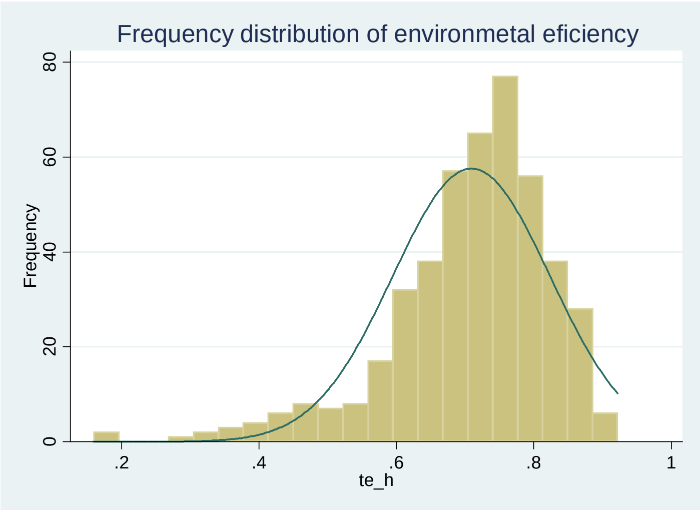

Figure 1 Frequency distribution of environmental technical efficiency

Around 56% of the household have environmental technical efficiency scores above the average.

Determinants of environmental inefficiency

The next step in our analysis is the identification of farm and household characteristics that can explain the difference in environmental efficiency. As stated before, the main objective of this paper is to verify if there is a significant relationship between the level of market integration of the household and the environmentally friendly farming practices.

To estimate Equation 3, we use the predicted environmental technical efficiency scores from stage one of the analysis as a dependent variable. Since the efficiency scores take a value between zero and one, the common approach in the literature is to use Tobit regression (Chavas *et al.*, 2005;Rios *et al.*, 2005;Wossink *et al.*, 2006;Hoff, 2007).

Following Lovell *et al.* (1994), we are going to use the following transformation to unbound the depended variable and then use OLS:

$$ee = \ln\left(\frac{1}{EE} - 1\right) \qquad (7)$$

where EE represents the predicted environmental technical efficiency score obtained in the previous stage. In this case, (1/EE-1) represents the proportional decrease in nitrogen surplus that can be achieved with the same amount of inputs. Since nitrogen surplus is considered a "bad" output produced by the agricultural household, then this term can be considered as environmental efficiency.

The OLS results explaining the variation in environmental efficiency are reported in Table 7. Gender and education of household head were found insignificant.

Since both environmental efficiency and market integration index are calculated using the quantity of outputs produced, there is a risk of endogeneity which may lead to biased OLS estimates.

The correlation between the independent variables and the error term is zero and the homoskedasticity assumption is not violated[13].

Table 6 OLS regression results

Variable	Coef.	Std. Err.
Market integration	-0.618***	0.102
Age	0.006**	0.003
Gender	-0.069	0.072
_Ihowfarm_2	-0.078	0.076
_Ihowfarm_3	0.277***	0.076
_Imain_emp~2	-0.155**	0.073
_Imain_emp~3	-0.286**	0.113
_Imain_emp~4	-0.163**	0.086
Household size	-0.001	0.018
_Ieducatio~2	-0.149	0.223
_Ieducatio~3	-0.159	0.223
_Ieducatio~4	-0.263	0.245
_cons	-0.800***	0.278

The findings show that market integration level has a strong negative effect on environmental efficiency. The negative sign of the coefficient suggests that if agricultural household increases the proportion of marketable output that it sells, then the environmental efficiency of the household decreases.

While gender of household head was found statistically insignificant, the age of household head has a positive and significant effect on ee, although it is small in magnitude. Farming mainly manually (_Ihowfarm_3) has a positive effect on ee compared to farming mainly using agricultural machinery.

The main employment of the household head seems to have a significant impact on environmental efficiency of the household. If the household head's main employment is not working on the own land, then the environmental efficiency of the household is lower compared to the households where the household head is mainly involved in the agricultural activity on own farm.

Conclusion

Environmental efficiency analysis has an important role in promoting policies aiming at reducing the pollution generated by agricultural activity. Using a hyperbolic distance function, the impact of market integration and different household characteristics on environmental efficiency is evaluated.

Our results suggest that there is a trade-off between an increase in commercialisation and the production of negative externalities, and this trade-off must be taken into consideration by policy makers while discussing the shape of the CAP post-2013. Given the huge number of small farms in NMS and their concentration is certain areas (often environmentally fragile areas), the environmental consequences of policy incentives to stimulate market integration might be significant. A right balance between the objectives of competitiveness, on the one hand, and environmental benefits, on the other, has to be struck. The main contribution of our analysis is that it shows in a rigorous quantitative way that there are economics grounds for public support to semi-subsistence farms based on the externality

[13] A Breusch-Pagan / Cook-Weisberg test for heteroskedasticity was performed and homoskedasticity cannot be rejected at 5% significance level.

argument. The form of this support and the way to be disbursed in order to reach the millions of predominantly subsistence farmers at reasonable administrative costs, are issues where a more active policy debate involving all rural stakeholders is necessary. While currently commercial farms are rewarded for using good farming practices, small subsistence-orientated farms do not receive any payment for their share in the provision of environmental goods, a situation that needs to be changed in future.

References:

Aiken, D. V. (2006). Application of the distance function to nonmarket valuation of environmental goods and services: An illustrative example. *Ecological Economics,* 60(1), 168-175.

Areal, F. J.,R. Tiffin and K. G. Balcombe (2009). *Provision of environmental output within a multi-output distance function approach*. In: *Agricultural Economics Society* Dublin.

Bailey, A. P., *et al.* (1999). Towards a method for the economic evaluation of environmental indicators for UK integrated arable farming systems. *Agriculture, Ecosystems & Environment,* 72(2), 145-158.

Battese, G. E. (1997). A NOTE ON THE ESTIMATION OF COBB-DOUGLAS PRODUCTION FUNCTIONS WHEN SOME EXPLANATORY VARIABLES HAVE ZERO VALUES. *Journal of Agricultural Economics,* 48(1-3), 250-252.

Birol, E.,M. Smale and Á. Gyovai (2004). *Agri-environmental policies in a transitional economy: the value of agricultural biodiversity in Hungarian home gardens*. International Food Policy Research Institute (IFPRI).

Bontems, P.,G. Rotillon and N. Turpin (2004). *Improvement of water quality as a joint production of milk when dairy farms are heterogeneous*. In: *90th EAAE Seminar "Multifunctional agriculture, policies and markets: understanding the critical linkages"* Rennes, France.

Brouwer, F. (1998). Nitrogen balances at farm level as a tool to monitor effects of agri-environmental policy. *Nutrient Cycling in Agroecosystems,* 52(2), 303-308.

Brush, S. B.,J. E. Taylor and M. R. Bellon (1992). Technology adoption and biological diversity in Andean potato agriculture. *Journal of Development Economics,* 39(2), 365-387.

Chavas, J.-P.,R. Petrie and M. Roth (2005). Farm Household Production Efficiency: Evidence from The Gambia. *American Journal of Agricultural Economics,* 87(1), 160-179.

Coelli, T.,L. Lauwers and G. Van Huylenbroeck (2007). Environmental efficiency measurement and the materials balance condition. *Journal of Productivity Analysis,* 28(1), 3-12.

Coelli, T. and S. Perelman (2000). Technical efficiency of European railways: a distance function approach. *Applied Economics,* 32(15), 1967-1976.

Coelli, T. J., *et al.* (2005). *An introduction to efficiency and productivity analysis*. Second Edition edn.: Springer.

Cuesta, R. A.,C. A. K. Lovell and J. L. Zofío (2009). Environmental efficiency measurement with translog distance functions: A parametric approach. *Ecological Economics,* 68(8-9), 2232-2242.

Di Falco, S.,M. Bezabih and M. Yesuf (2009). Seeds for livelihood: Crop biodiversity and food production in Ethiopia. *Ecological Economics,* 69(8), 1695-1702.

Di Falco, S., *et al.* (2008). *Agrobiodiversity, Farm Profits and Land Fragmentation: Evidence from Bulgaria* Unpublished mimeo.

Ebert, U. and H. Welsch (2007). Environmental Emissions and Production Economics: Implications of the Materials Balance. *American Journal of Agricultural Economics,* 89(2), 287-293.

European Commission (2002). *Agricultural Situation in the Candidate Countries: Country Report on Romania*. (ed. Directorate General for Agriculture).

European Council (2005). *COUNCIL REGULATION (EC) No 1698/2005 of 20 September 2005 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD).* In: *L 277/1* (ed. Official Journal of the European Union).

Färe, R. and S. Grosskopf (1998). Shadow Pricing of Good and Bad Commodities. *American Journal of Agricultural Economics,* 80(3), 584-590.

Färe, R.,S. Grosskopf and F. Hernandez-Sancho (2004). Environmental performance: an index number approach. *Resource and Energy Economics,* 26(4), 343-352.
Färe, R., *et al.* (1989). Multilateral Productivity Comparisons When Some Outputs are Undesirable: A Nonparametric Approach. *The Review of Economics and Statistics,* 71(1), 90-98.
Fare, R., *et al.* (1993). Derivation of Shadow Prices for Undesirable Outputs: A Distance Function Approach. *The Review of Economics and Statistics,* 75(2), 374-380.
Färe, R.,S. Grosskopf and D. Tyteca (1996). An activity analysis model of the environmental performance of firms--application to fossil-fuel-fired electric utilities. *Ecological Economics,* 18(2), 161-175.
Fernandez, C.,G. Koop and M. F. J. Steel (2002). Multiple-Output Production with Undesirable Outputs: An Application to Nitrogen Surplus in Agriculture. *Journal of the American Statistical Association,* 97(458), 432-442.
Hadri, K. and J. Whittaker (1999). EFFICIENCY, ENVIRONMENTAL CONTAMINANTS AND FARM SIZE: TESTING FOR LINKS USING STOCHASTIC PRODUCTION FRONTIERS. *Journal of Applied Economics,* 2(2), 337.
Havlik, P., *et al.* (2005). Joint production under uncertainty and multifunctionality of agriculture: policy considerations and applied analysis. *Eur Rev Agric Econ,* 32(4), 489-515.
Heidhues, F. and M. Brüntrup (2003). Subsistence Agriculture in Development: Its Role in Processes of Structural Change. *In*: Frohberg, S. A. a. K. ed. *Subsistence Agriculture in Central and Eastern Europe: How to Break the Vicious Circle?* Vol. 22. IAMO.
Hodge, I. (2008). To What Extent are Environmetal Externalities a Joint Product of Agriculture? Overview and Policy Implications. *In*. *Multifunctionality in Agriculture: Evaluating the Degree of Jointness, Policy Implications*. OECDPublishing, pp. 85-118.
Hoff, A. (2007). Second stage DEA: Comparison of approaches for modelling the DEA score. *European Journal of Operational Research,* 181(1), 425-435.
Huang, H. and P. Leung (2007). Modeling protected species as an undesirable output: The case of sea turtle interactions in Hawaii's longline fishery. *Journal of Environmental Management,* 84(4), 523-533.
Kelly, T. C.,Y.-c. Lu and J. Teasdale (1996). Economic-environmental tradeoffs among alternative crop rotations. *Agriculture, Ecosystems & Environment,* 60(1), 17-28.
Lankoski, J. and M. Ollikainen (2003). Agri-environmental externalities: a framework for designing targeted policies. *Eur Rev Agric Econ,* 30(1), 51-75.
Latruffe, L.,S. Davidova and K. Balcombe (2008). Application of a double bootstrap to investigation of determinants of technical efficiency of farms in Central Europe. *Journal of Productivity Analysis,* 29(2), 183-191.
Le Cotty, T. and L.-P. Mahe (2008). Domestic and International Implications of Jointness for an Effective Multifunctional Agriculture: Some Evidence from Sheep Raising in Lozere. *In*: OECD ed. *Multifunctionality in Agriculture: Evaluating the Degree of Jointness, Policy Implications*. OECDpublishing, pp. 213-226.
Lovell, C. A. K., *et al.* (1990). *Resources and functionings : a new view of inequality in Australia*. 0909591857 :. Adelaide, University of Adelaide, Dept. of Economics.
Lovell, C. A. K.,L. C. Walters and L. L. Wood (1994). Stratified Models of Education Production using Modified DEA and Regression Analysis. *In*: CHARNES, A., *et al.* eds. *Data Envelopment Analysis – Theory, Methodology, and Applications*. Norwell: Kluwer Academic Publishers.
Nehring, R., *et al.* (2003). Manure and Commercial Fertilizer Nutrients Relative to Cropland and Pasture Requirements: Is the Pollution Risk Growing on Corn/Livestock Farms? (21980).
OECD (1998). *The Environmental Effects of Reforming Agricultural Policies*. SourceOECD Agriculture & Food.
OECD (2001). *Multifunctionality: Towards an analytical framework*. Paris: OECD.
OECD (2005a). *FARM STRUCTURE AND FARM CHARACTERISTICS - LINKS TO NON-COMMODITY OUTPUTS AND EXTERNALITIES*. AGR/CA/APM(2004)11/FINAL. Paris,
OECD (2005b). *Multifunctionality in agriculture : what role for private initiatives?* . Paris: Organisation for Economic Co-operation and Development.
Omer, A.,U. Pascual and N. P. Russell (2007). Biodiversity Conservation and Productivity in Intensive Agricultural Systems. *Journal of Agricultural Economics,* 58(2), 308-329.

Rahman, S. and M. K. Hasan (2008). Impact of environmental production conditions on productivity and efficiency: A case study of wheat farmers in Bangladesh. *Journal of Environmental Management*, 88(4), 1495-1504.
Reinhard, S. (1999). *Econometric analysis of economic and environmental efficiency of Dutch dairy farms*. Wageningen University. PhD Thesis.
Reinhard, S.,C. A. K. Lovell and G. Thijssen (1999). Econometric Estimation of Technical and Environmental Efficiency: An Application to Dutch Dairy Farms. *American Journal of Agricultural Economics,* 81(1), 44-60.
Reinhard, S.,C. A. K. Lovell and G. Thijssen (2002). Analysis of Environmental Efficiency Variation. *American Journal of Agricultural Economics,* 84(4), 1054-1065.
Renkow, M. (1990). Household Inventories and Marketed Surplus in Semisubsistence Agriculture. *American Journal of Agricultural Economics*, 72(3), 664-675.
Rios, A. R.,W. A. Masters and G. E. Shively (2008). *Linkages between Market Participation and Productivity: Results from a Multi-Country Farm Household Sample*. Selected Paper 461840. American Agricultural Economics Association, 2008 Annual Meeting, July 27-29, 2008, Orlando, Florida.
Rios, A. R. and G. E. Shively (2005). *Farm size and nonparametric efficiency measurements for coffee farms in Vietnam*. American Agricultural Economics Association (New Name 2008: Agricultural and Applied Economics Association).
Shively, G. E. (2006). Externalities and labour market linkages in a dynamic two-sector model of tropical agriculture. *Environment and Development Economics,* 11(01), 59-75.
Toquero, Z., *et al*. (1975). Marketable Surplus Functions for a Subsistence Crop: Rice in the Philippines. *American Journal of Agricultural Economics,* 57(4), 705-709.
Van Dusen, E. and J. E. Taylor (2005). Missing markets and crop diversity: evidence from Mexico. *Environment and Development Economics*, 10(04), 513-531.
Wossink, A. and Z. S. Denaux (2006). Environmental and cost efficiency of pesticide use in transgenic and conventional cotton production. *Agricultural Systems,* 90(1-3), 312-328.