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'External Cost of Farming Activities: Economic Evaluation, Risk Considerations, Environmental Repercussions and Regulatory Framework'

Technical efficiency and environmental pressures of pig farms in Hungary

Laure Latruffe

INRA,
UMR 1302 SMART,
F-35000 Rennes, France
and
Agrocampus Ouest,
UMR 1302 SMART,
F-35000 Rennes, France
laure.latruffe@rennes.inra.fr

Yann Desjeux

INRA,
UMR 1302 SMART,
F-35000 Rennes, France
and
Agrocampus Ouest,
UMR 1302 SMART,
F-35000 Rennes, France
yann.desjeux@rennes.inra.fr

József Fogarasi

AKI, Research Institute of
Agricultural Economics,
Budapest, Hungary
Fogarasi.Jozsef@aki.gov.hu
and
Partium Christian University,
Oradea, Romania
fogarasi@partium.ro

Zoltán Bakucs

Institute of Economics,
Academy of Sciences,
Budapest, Hungary
bakucs@econ.core.hu

Imre Fertő

Corvinus University of
Budapest, Hungary
imre.ferto@uni-corvinus.hu
and
Institute of Economics,
Academy of Sciences,
Budapest, Hungary
ferto@econ.core.hu

Abstract

Pig farming is one of the strongest polluters of water resources due to its intensive production techniques and slurry rejection. Several European countries have already introduced environmental regulations aiming at reducing the pollution caused by nitrates from agricultural sources, but not yet Hungary.

This paper investigates how Hungarian pig farms would be affected if such regulations are to be enforced.

We calculate farm technical efficiency separately for two types of pig production systems – namely farrowing only and farrow-to-finish farms (FAFI farms) and finishing only farms (FI farms) – using 2001 data on pig activity and Data Envelopment Analysis (DEA). We then investigate whether environmental regulations would affect the farms' technical efficiency, with the help of a second-stage regression and various environmental pressure proxies.

Results indicate that the pollution could be reduced with no impact on the output level, and that Hungarian pig farmers have incentives to reduce nitrogen pollution in order to increase their efficiency even in the absence of regulation.

Keywords: technical efficiency, DEA, pig farms, nitrate pollution, Hungary

1. Introduction

Pig farming is one of the strongest polluter of water resources in developed countries, due to its intensive production techniques and slurry rejection. Several countries have already introduced environmental regulations aiming at reducing nitrate and phosphorus waste from pig farming. For example, in Taiwan the government introduced in 1987 a law aiming at limiting the level of waste from pig farms (Yang *et al*., 2009). In the European Union (EU) since 1991 the Council Directive 91/676/EEC (referred hereafter to as the EU Nitrate Directive*)* aims at promoting the protection of waters against pollution caused by nitrates from agricultural sources. Besides other prescriptions, this EU regulation requires that, for each farm, the amount of nitrogen (N) produced by livestock and spread on agricultural land each year shall not exceed a specified amount per hectare (i.e. 170 kg N). In France livestock farms can spread manure either on their own land or on land of other farms (Piot-Lepetit and Le Moing, 2007; Larue and Latruffe, 2009). In the Netherlands farms are required to reduce their pollution caused by nitrates from agricultural sources since 1998 and can adopt the Green Label systems, which are certified less nitrogen polluting pig production systems (Oude Lansink and Reinhard, 2004).

Whether such regulations modify pig producers' decisions regarding their localisation, production scale and input use has been recently investigated in the literature. For example, Larue *et al*. (2008) show that the EU regulation regarding the threshold for the nitrogen spread on agricultural land had a negative impact on pig farms' concentration in Denmark, and that the dispersion effect is more pronounced in 2004 than in 1999. Piot-Lepetit and Le Moing (2007) provide evidence of a positive relationship between farms' technical efficiency and environmental regulation in the French pig sector during 1996-2001, suggesting that pig producers introduced changes in their production process. Larue and Latruffe (2009) confirm this finding with data from 2004, but suggest in addition that the reverse effect may arise (i.e. a decrease in technical efficiency) if the environmental regulation is too stringent in the way that it forces pig producers to spread their manure on land that is far from their farm. By contrast, in Taiwan Yang *et al*. (2008) do not find a clear-cut effect of the 1987 environmental law on pig farms' technical efficiency in 2003-2004.

This paper investigates how environmental pressures, focusing on nitrate production, may affect the efficiency of pig farms in Hungary. After the accession, Hungary adopted the EU environmental directives, but they are implemented only gradually, within several years. This paper therefore aims at shedding light on how Hungarian pig farms would be affected once the EU Nitrate Directive is fully implemented and applied.

In accordance with the EU Nitrate Directive the Water Quality Supervision Network has been established in Hungary. Within this frame, it has been assessed that 48% of country's surface may be considered nitrate sensitive area. In 1998 the total slurry output of Hungarian animal breeding plants amounted to 11 million tons. Approximately 30% of it (3.4 million tons) were produced by farms located in nitrate sensitive areas. For farms located in these areas, a single action programme (instead of regional specific programmes) considering manure-waste management was adopted.

Figure 1 presents Hungarian nitrate sensitive areas, and surface waters' pollution levels.

- insert Figure 1 here -

The regulation and standards of manure storage buildings under the EU Nitrate Directive are introduced gradually in Hungary. Large livestock farms (i.e. above 40,000 heads in case of poultry farming, and 20,000 heads of pigs or 750 heads of sows in case of pig farming) have already been operating their manure storage capacities according to the EU Nitrate Directive since 31 October 2007 (amounting to 9% of pig farms and 0,2% of sow breeding farms in 2005). The deadline for farms situated in drinking-water drainage areas was 31 October 2009. For other farms situated in nitrate sensitive areas, the expected implementation has to happen by 2013. Due to the structural changes within the agricultural sector, pig farming in Hungary has been declining since the beginning of the transition period: the livestock has decreased from 8.45 million pigs in 1990 to 3.33 million pigs in 2008. Accordingly, the environmental pollution of pig farms decreased as well, as the breeding intensity fell from 132 pigs per 100 hectares (ha) of utilised agricultural area (UAA) in 1990 to 58 pigs per 100 ha UAA in 2008.

The paper is structured as follows. The second section introduces the methodology and data. The third section describes the results, and the last section concludes.

2. Methodology and data

Nitrates are an undesirable output of pig activity, that is to say an output that is socially undesirable due to its negative externalities, in particular air and water pollution (Oude Lansink and Reinhard, 2004). In efficiency analysis, undesirable outputs may be modelled as 'bad' outputs that is to say as inputs, under the assumption of either strong, respectively weak, disposability (i.e. assuming either that it is not costly, respectively costly, to reduce them); or they can be included as 'good' outputs by using in a first stage a transformation function (Yang *et al*., 2008). In this paper, we consider nitrogen from pig activity sources as a strongly disposable input.

We use farm-level data extracted from a specific survey of pig producers in Hungary in 2001. The total sample includes 192 farms. Farms are separated into two groups based on their specialisation: farrowing only and farrow-to-finish farms (FAFI farms, 140 farms), and finishing only farms (FI farms, 52 farms). Considering that technologies differ between these two specialisations, an efficient frontier is constructed for each group separately. Frontiers are constructed with the non-parametric method Data Envelopment Analysis (DEA) that is based on linear programming for enveloping all observations in the sample (see Charnes *et al*., 1978, and Coelli *et al*., 2005). The best farms create the frontier, and are assigned an efficiency score of 1, while the less efficient farms are within the frontier. The distance to the frontier represents the efficiency level, with the furthest the farm, the lowest its efficiency level and the lowest its efficiency score (between 0 and 1). Inputs and outputs used in the DEA model do not relate to the whole farm production system, but only to the pig activity on the farm.

Firstly, technical efficiency is calculated without accounting for waste emissions. For FAFI farms, the two outputs used are the number of piglets sold and the number of pigs fattened on farm, while the five inputs include the number of piglets and pigs purchased, the number of sows, the number of labour hours spent on the porcine activity, the values of feed, and other costs. For FI farms, the single output is the number of pigs fattened on farms, while the four inputs are similar to the inputs for FAFI farms except that the number of sows is not included. Next, technical efficiency is calculated again for both types of farms still using separate frontiers, with the inclusion of an additional input, namely the quantity of nitrogen produced. Nitrogen production from pig activity is quantified here with the method of measurement applied by French Authorities to enforce the EU Nitrate Directive; each pig head is assigned a nitrate-equivalent production coefficient depending on its type (sow, swine, piglets etc), representing the nitrogen quantity produced per year (CORPEN, 2003). Table 1 provides descriptive statistics of the data used in the DEA models. The quantity of nitrogen emitted by FAFI farms is much higher on average than the one emitted by FI farms: 3,515 against 283 kg N.

- insert Table 1 here -

Secondly, we investigate the role of several factors on the technical efficiency of both types of pig farms using a second-stage regression with ordinary least squares. A single equation is estimated, that is to say both samples (FAFI and FI farms) are merged together. The explanatory variables are characteristics of the farms in the merged sample from the specific farm survey, and regional characteristics extracted from various sources. The level of the regions considered is the NUTS2 level from the European classification of Nomenclature of Units for Territorial Statistics (NUTS). In Hungary there are seven NUTS2 regions. Several variables were tested in the model. The variables retained for the final specification include the following farms' characteristics.

- Their total UAA in ha and their total number of livestock units, both proxying the farm size. No expectation is made on the sign of the impact, as existing literature on the relationship between farm efficiency and farm size provides contradictory evidence.
- The share of the farms' revenue stemming from the pig activity to proxy farm specialisation *vs*. diversification. No expectation is made on the sign of the impact, as both effects may arise: on the one hand, diversified farms may be less efficient than specialised farms due to possible conflicts in input use; on the other hand, diversification may increase efficient by decreasing production risk.
- The share of the farm's revenue stemming from subsidies to proxy the role of public support. A negative impact is expected, as it is generally found in the empirical literature that public support decreases farm technical efficiency due to farmers' reduced effort and motivation.
- The farm UAA divided by the quantity of nitrogen produced on the farm. The idea is to use a variable that captures the pressure faced by the farms in terms of land availability to spread their own manure. The quantity of nitrogen produced per ha of UAA was an obvious choice, however, as some farms have no UAA at all, such variable was reducing the number of observations used in the econometric regression. Therefore, the inverse, namely the number of ha available per kg of nitrogen produced, is used instead, the variable taking the value 0 for farms with no UAA. In France, due to the limit on manure spreading per ha, the expectation would be that the more land available (i.e. the larger the variable used), the more efficient the farm; indeed, less land available would imply to spread manure on other farms and thus may result in conflict in labour time or machinery use between production and manure spreading. However, in Hungary, as no regulation has been introduced yet, no *a priori* expectation can be made on the impact of this variable.

Regarding regional data, the variables used in the final model are as follows.

- The number of feed factories per pig farm proxies the availability of pig feed and the development of the upstream market, and thus a positive effect is expected.
- The population is introduced as proxy for environmental pressures, as inhabitants are disturbed by emissions and may press local governments for regulation; thus a positive sign is expected.
- Finally, the role of environmental pressure on farms' technical efficiency is also analysed with the introduction of the total level of nitrogen produced by livestock in the region (calculated from CORPEN, 2003), as a ratio per ha of regional UAA in the region where the farm is located. Again, no expectation can be made on the sign of the impact for this variable.

Other regional variables were tested in the model, such as the regional income per capita as an additional environmental pressure variable, and the regional number or capacity of slaughterhouses per pig farm in the region as a proxy for the development of the downstream market. However, the variables were collinear with the other variables and were thus not included in the final specification. Table 2 provides some descriptive statistics of the variables used.

- insert Table 2 here -

The regional average quantity of nitrogen per ha of UAA is only 19.4 kg, which is still very far from a possible pollution limit that could be introduced in Hungary (for example the limit in France is 170 kg per ha).

Most studies use Ordinary Least Squares (OLS) methods for the second-stage regression. Quantile regression (originally developed by Koenker and Bassett, 1978) techniques possess however some favourable characteristics when compared to OLS. First, it does not require specific distributional assumptions (e.g. normality) for the dependent variable. Second, if it is expected that covariates have different effects across alternative points of the conditional distribution of the dependent variable, quantile regression can follow the changes and significance of the estimates. Finally, quantile regression is very robust compared to OLS when the possible effect of outliers upon the conditional mean is considered. Following Lotti *et al*. (2003), the θ^{th} sample quantile, where $0 < \theta < 1$, can be defined as:

$$\min_{b \in R} \left[\sum_{i \in \{i: y_i \geq b\}} \theta |y_i - b| + \sum_{i \in \{i: y_i < b\}} (1-\theta) |y_i - b| \right] \quad (1)$$

For a linear model $y_i = \beta' x_i + \varepsilon_i$, the θ[th] regression quantile is the solution of the following minimization problem, similar to equation (1):

$$\min_{b \in R^k} \left[\sum_{i \in \{i: y_i \geq x_i b\}} \theta \left| y_i - x_i b \right| + \sum_{i \in \{i: y_i < x_i b\}} (1-\theta) \left| y_i - x_i b \right| \right] \tag{2}$$

Solving (2) for *b* provides a robust estimate of the parameter, and thus by changing θ from 0 to 1 any quantile of the conditional distribution may be considered. Moreover, the constant change of θ relaxes the IID assumption of the error terms.

Finally, the Bierens and Ginther’s (2001) Integrated Conditional Moment (ICM) test is used to test the appropriateness of the quantile regression models’ functional form.

3. Results

Table 3 shows the averages of efficiency scores obtained with the DEA models, and Figure 2 their probability distribution.

- insert Table 3 here –

- insert Figure 2 here -

Results indicate that the technical efficiency (assuming constant returns to scale) is higher on average for FAFI farms than for FI farms: 0.553 against 0.423, the difference being tested significantly different from zero at one percent. This suggests that the farrowing activity alone or combined with the finishing activity is more technically efficient than the finishing activity alone. However, this conclusion holds when pollution from the pig activity is not considered. Indeed, FAFI farms may be more efficient, but, on the other hand, they have a higher number of pig heads, and produce more waste as shown by Table 1. Indeed, when technical efficiency is calculated again for each type of farms with the inclusion of an additional input, namely the quantity of nitrogen produced, results differ from the efficiency results obtained when not accounting from nitrate pollution. When nitrate waste is considered, the mean technical efficiency of FAFI farms is only slightly higher than that of FI farms, 0.568 against 0.546, the difference not being significantly different from zero. These figures suggest that both types of farms could reduce their nitrate pollution by more than 40 percent and still produce the same output level. Thus, if environmental regulations are introduced in Hungary, they may not affect the level of pig production in the country, as there is a substantial room for pollution reduction keeping the pig output constant.

However, environmental regulations may affect Hungarian pig farms' technical efficiency. This issue is investigated with the help of the second-stage regression, whose results are provided in Table 4. Explanatory variables were scaled, in order to facilitate the interpretation of results. First we report coefficient estimates obtained by OLS, followed by quantile regression estimates for 0.10, 0.25, 0.50, 0.75 and 0.90 quantiles (pictured on Figure 3). The last column of Table 4 reports the results of a Wald test for equality of estimated coefficients across quantiles.

- insert Table 4 here -

- insert Figure 3 here -

Normality tests (skewness/kurtosis and Shapiro-Wilk tests) reject the normal distribution hypothesis of the DEA scores at the 5% level of significance, emphasising the appropriateness of quantile regression method *versus* OLS. When using OLS, it is firstly worth noting that none of the farms' specific characteristics have a significant effect on their technical efficiency, by contrast to regional variables. Differences in significance can be observed between quantiles, however significant variables have the same sign with OLS estimates and across quantiles. Size in terms of UAA has no significant effect in OLS, but has a significantly positive effect in upper quantiles. The null hypothesis of coefficient equality is not rejected, implying that UAA has the same effect upon farms' technical efficiency, regardless whether they are less or more efficient. The number of livestock units on the farm is a significant variable with a rather low negative impact for the 0.25-0.90 quantiles, the null of coefficient equality not being rejected by the Wald test. Interestingly, the share of revenue from pig activity on farms, a proxy for specialisation, is not significant in OLS and in any quantiles. Based on previous literature (e.g. Bakucs *et al*., 2010), a negative sign is expected for the government subsidies variable. A large negative impact is however only found for the 0.5 quantile, the impact being non-significant for the other quantiles. Regarding farms' UAA per nitrogen quantity produced, it is not surprising that it does not significantly influence farms technical efficiency: emission control regulation is only partly applied in Hungary and the nitrogen output of Hungarian pig farms is still lower than those experienced in EU-15 countries (see previous section). Regional variables are significant in OLS and for all quantiles, except the lowest one. The number of feed factories per pig farm in the regions presents a positive and significant coefficient conform to the expectation, indicating that the closeness and development of the upstream market is important for pig producers' performance. The coefficient's size however significantly varies across quantiles, from 40.63 in the 0.25 quantile to 89.70 in the 0.75 quantile. Regarding the environmental proxies, the population has the expected positive significant coefficient, suggesting that highly populated areas put pressures on the producers to become more efficient. The magnitude of estimated coefficients across quantiles are similar (and quite low), but the Wald test rejects the equality of coefficients. Such neighbourhood effect has also been given evidence in France by Larue and Latruffe (2009). Finally, the regional quantity of nitrogen produced per ha has a negative significant impact on farms' technical efficiency for both OLS and quantile estimates, while the inverse ratio calculated for the sample's farms had no significant influence on efficiency. Quantile coefficient estimates are significantly different, and the magnitude increases from lower quantiles towards higher ones. This finding suggests that what matters is not land availability within the farm, but land availability within the region, and that there may be some congestion effects or some competition for land. ICM tests in Table 5 confirm the appropriateness of quantile regression methods.

- insert Table 5 here -

4. Conclusion

This paper has analysed the relationship between the technical efficiency of farms specialised in pig production and the environmental pressures they are facing or may face in the future in Hungary. Pig farms' technical efficiency was calculated with pig activity data, including the quantity of nitrogen produced by livestock as a strongly disposable undesirable output. It was then regressed on several farms' characteristics and on variables specific to the region where each farm is located. Both standard OLS and quantile regression estimations were applied. The DEA scores' normality tests, the quantile regression appropriateness ICM tests, and the significance of variables through various quantiles, support the use of quantile regression. Results indicated that neighbourhood pressures regarding environmental pollution increased farms' technical efficiency, while congestion problems due to a large regional nitrogen production reduced the efficiency.

If the EU regulation governing livestock activities were to be fully applied in Hungary and the total quantity of nitrogen produced by livestock had to be less than a specific threshold per ha, our findings suggest that Hungarian pig farmers' technical efficiency would not decrease. Firstly, the level of nitrogen per ha (namely 19.4 kg on average) is still very low (much lower than the authorised limit in France for example), and therefore there would still be room for manoeuvre. Secondly, the econometric regression revealed a negative effect of the regional nitrogen quantity per ha on the farms' technical efficiency, indicating that farmers currently have no benefit in increasing the pollution in their region.

This analysis is the first one shedding light on the link between environmental pressures and farm technical efficiency in Hungary. Future research may consider the possibilities by farms to reduce their manure by treating it instead of spreading it on land. The impact of a potential regulation on pollution limits may be assessed in conjunction with the influence of a potential government support in treatment plants.

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Table 1: Descriptive statistics of the farm-level data used in the DEA models (averages)

	Farrow-to-finish (FAFI) farms (140 farms)	Finishing only (FI) farms (52 farms)
Desirable outputs		
Number of piglets sold	3,052	
Number of pigs fattened on farm	99	485
Undesirable output		
Quantity of nitrogen produced (kg N)	3,515	283
Inputs		
Number of sows	98	
Number of piglets and pigs purchased	1,759	79
Labour spent on pig activity (hours)	4,445	2,030
Pig feed (euros)	22,039,746	3,965,781
Other costs for pig activity (euros)	35,492,699	4,539,934

Table 2: Descriptive statistics of the data used in the second-stage regression (sample's averages)

	Farrow-to-finish (FAFI) and finishing only (FI) farms together (192 farms)
Sample's characteristics	
Sample's farms' UAA (ha)	190.9
Sample's farms' total number of livestock units	2,634
Sample's farms' share of revenue from pig activity in farm revenue (%)	41.7
Sample's farms' share of subsidies in farm revenue (%)	7.9
UAA per nitrogen quantity produced (ha/kg)	0.311
Regional characteristics	
Regional population (inhabitants) [a]	1,235,725
Number of feed factories per pig farm in the region [b]	0.012
Nitrogen quantity per ha of UAA in the region (kg) [c]	19.4

Sources of the regional characteristics:

[a] Hungarian Statistical Office (2006)

[b] Holló-Szabó and Kertai (2008)

[c] Calculated from the 2000 Hungarian Agricultural Census and the French coefficients of CORPEN (2003)

Table 3: Descriptive statistics of the efficiency scores (averages)

	Farrow-to-finish (FAFI) farms (140 farms)	Finishing only (FI) farms (52 farms)
Without the undesirable output	0.553	0.423
With the undesirable output	0.568	0.546

Table 4: Results of the second-stage regression

		quantile regressions					
	OLS	0.10	0.25	0.50	0.75	0.90	Wald test
Intercept	-0.391**	-0.126	-0.201	-0.642***	-0.747***	-0.867***	0.0465
Sample's farms' UAA	0.026	-0.018	0.062***	0.064	0.068**	0.054**	0.6403
Sample's farms' total number of livestock units	-0.001	0.001	-0.001**	-0.002**	-0.003***	-0.004***	0.8446
Sample's farms' share of revenue from pig activity in farm revenue	0.009	0.047	0.052	0.033	-0.008	-0.008	0.3533
Sample's farms' share of subsidies in farm revenue	-0.149	0.103	-0.106	-0.490**	-0.078	-0.013	0.8707
Sample's UAA per nitrogen quantity produced	-0.015	-0.004	-0.007	-0.001	-0.000	-0.019	0.9922
Regional population	0.001***	0.000*	0.001***	0.001***	0.002***	0.001***	0.0037
Number of feed factories per pig farm in the region	51.957***	16.468	40.638***	72.205***	89.703***	71.549***	0.0541
Nitrogen quantity per ha of UAA in the region	-0.049***	-0.019	-0.050***	-0.070***	-0.084***	-0.042***	0.0275
Number of observations				192			
R-squared	0.258						
Pseudo R-squared		0.1070	0.1545	0.2157	0.2161	0.1407	

Dependent variable: efficiency score calculated by including the undesirable output.

Sample: merged samples of FAFI and FI farms.

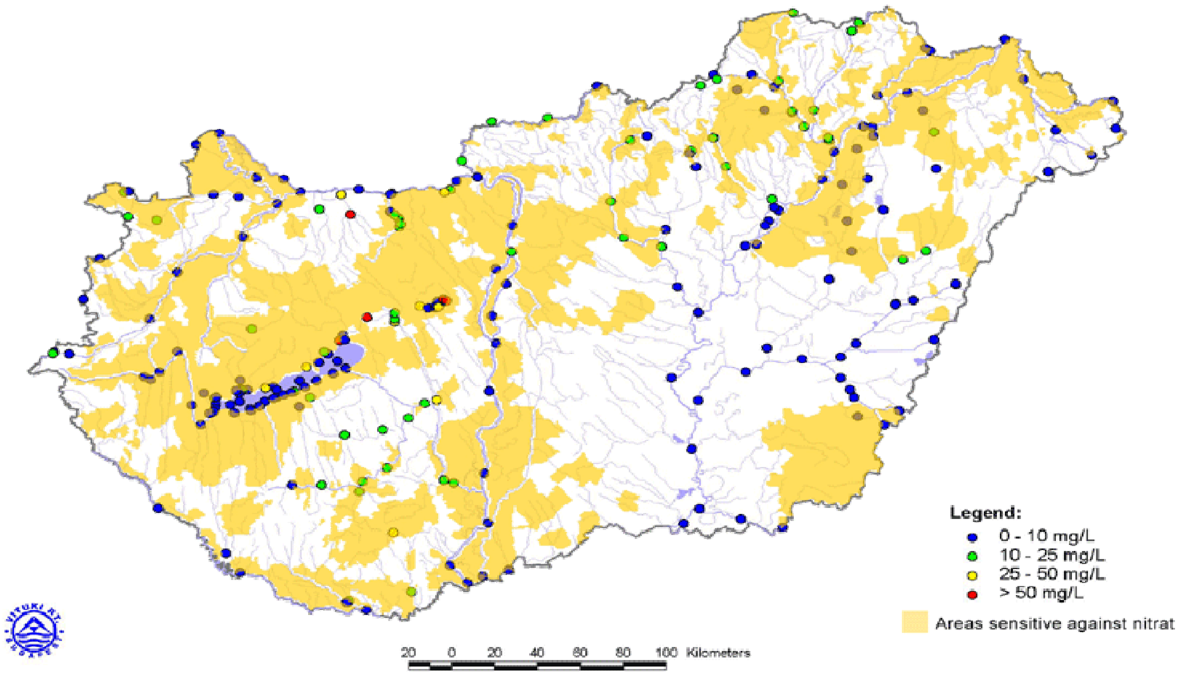
, *: significance at 5-percent, 1-percent level.

Table 5: Integrated Conditional Moment (ICM) tests

quantiles	c=1	c=5	c=10
0.10	0.176	0.268	0.173
0.25	0.311	1.166	0.597
0.50	0.776	1.614	1.545
0.75	0.594	1.026	1.080
0.90	0.780	1.076	1.083

Critical values: 10%: 3.23; 5%: 4.26

Figure 1: Nitrate sensitive areas and surface waters' NH_3 concentration in Hungary



Source: Mészáros György (2005)

Figure 2: Distribution of DEA scores

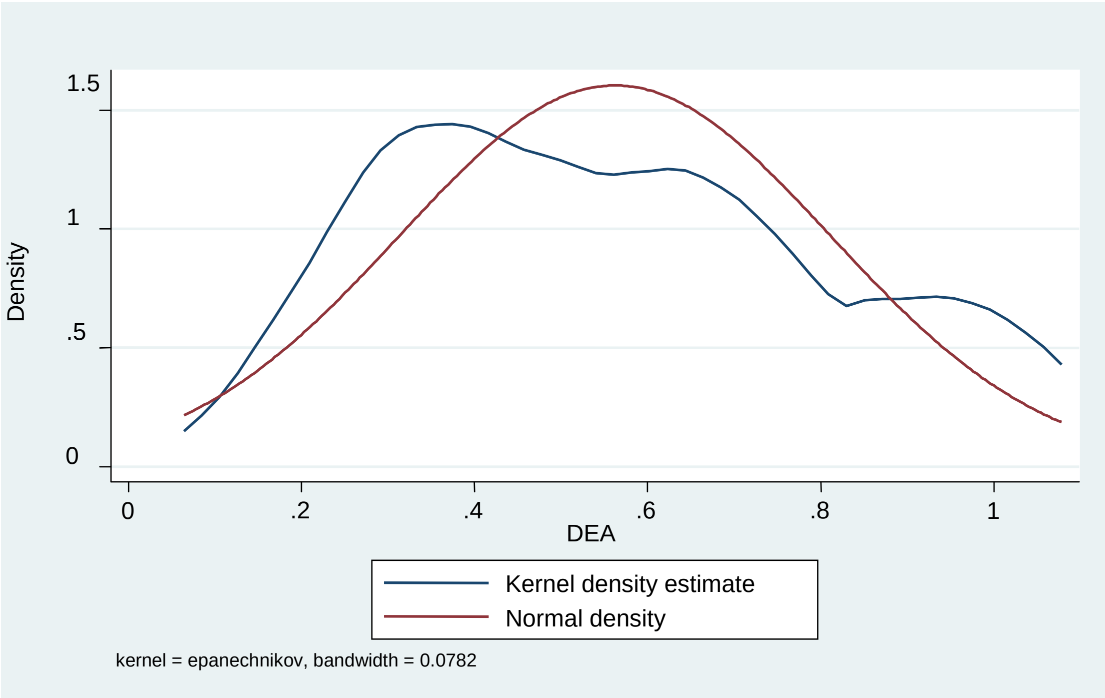


Figure 3. Quantile regression estimates for each explanatory variables