FACEPA

Farm Accountancy Cost Estimation and Policy Analysis of European Agriculture

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The disadvantage of farming in marginal agricultural regions and the potential loss of environmental values

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Executive Summary

The long term development of biodiversity is dependent on suitable habitats for plant and animal species. In this context, agriculture has an important role as a provider of biodiversity. This has been highlighted in the Swedish national environmental objectives, which explicitly point out the importance of agricultural landscapes. Still, a farm's provision of biodiversity is a joint production with commercial commodities, which implies that the supply of biodiversity may be sensitive to farm performance. If farms in a biodiversity-rich region are less efficient than others, there is a risk of a decline in agricultural production and hence a risk of a loss of biodiversity in these regions. In this paper we focus on the relationship between Swedish farms' efficiency and their provision of biodiversity, which is done by combining economic data (from the European FADN database) with information on biodiversity indicators (from the Swedish TUVA database) such as the number of plant species growing in a particular pasture. In total 266 farms with animal production are identified in 2003 and, for these farms, efficiency is estimated using the Data Envelopment Analysis (DEA) method. The efficiency score is then used in a second stage in order to assess the relationship between efficiency and biodiversity.

The first set of results stems from a regional analysis using a meta-frontier framework to determine regional (defined by NUTS1 regions) production frontiers. One finding is a distinct technological pattern showing Northern Sweden as a region with a technological disadvantage when it comes to agricultural production, which is as expected due to the cold climate and short growing season of the northern latitudes. However, only two (out of 60) plant species are primarily dependent (have more than 90 % of their locations) on the northern agricultural landscapes.

The second set of results is based on an analysis with the number of different species of vascular plants as the principal indicator of biodiversity. The main result is a negative correlation between farm efficiency and biodiversity in proximity to the farm. On the other hand, the provision of biodiversity at farm level is not correlated with efficiency. The role of biodiversity in surrounding areas stresses the importance of properties common to all farms in biodiversity-rich areas, which is strengthened by the lack of any significant relationship between biodiversity and efficiency when the landscape properties are removed from the biodiversity indicator.

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Abbreviations and Acronyms

EU	European Union
FACEPA	Farm Accountancy Cost Estimation and Policy Analysis of European Agriculture
FADN	Farm Accountancy Data Network
TUVA	Inventory of biodiversity in Swedish pastures
Ha	hectare

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1. Introduction

The development of biodiversity is dependent on suitable habitats for plant and animal species, and the agricultural landscape is a necessity for the long-term survival of many of them. The composition of species in the landscape will depend on regional differences in e.g. soil and micro climate, and thus a heterogeneous agricultural landscape is important. However, the products from agriculture are traded in a competitive market, and if farms in biodiversity-rich regions are less efficient producers, there is a risk of declining agriculture and thus a loss of biodiversity in these regions. In this paper we focus on the relation between farm efficiency and biodiversity in Sweden. The topic is highly politically relevant since Swedish environmental policy has a number of environmental objectives ("A rich diversity of plant and animal life" and "A varied agricultural landscape", www.miljomal.nu/english) for which agriculture is of special importance. No less than 40 % of Swedish red listed species are present in the agricultural landscape (Regeringskansliet, 2007). The most biodiversity-rich areas in the Swedish agricultural landscape are the semi-natural pastures.

Biodiversity in Swedish pastures has developed through long periods of continuous grazing of the land. These areas were created before urbanization and only a fraction of the areas grazed around 1900 is still maintained. Today, many such areas are located outside the major agricultural landscapes where soil and other landscape properties are not favorable for large scale production. At the same time modern technology makes grazing less economically attractive as compared to other production means. To support the provision of biodiversity, a pasture with biodiversity values can receive a support of about 100 Euro per hectare (ha) per year, and a pasture with premium values about 230 Euro. A number of technical restrictions on how to manage the pastures are imposed on a farmer joining the support scheme (e.g. restrictions on fertilization and grazing intensity), which is expected to decrease technical efficiency. Farms with premium values will have additional restrictions as compared to others. Efficiency might also be affected by soil quality and other landscape conditions. Many plant species require specific soil properties, shading (which is favored by small parcels), water conditions, etc. that are expected to put restriction on the production rationalization. Thus, the expected relation between efficiency and biodiversity is not justified by that an additional species of flower should influence the production possibilities, but by the fact that natural conditions and administrative restrictions promoting biodiversity will constrain farm practices. However, farm practices might of course influence biodiversity in the long run, and this combined with the cross sectional data used causes us to interpret the results in terms of correlations rather than a strict causality.

Biodiversity is a non-commodity output from agriculture which is jointly produced with other outputs. The joint production of commodity and non-commodity farm output has been highlighted in the economic literature by e.g. Romstad et al. (2000), Havlik et al. (2005) and Wossink and Swinton (2007). However, econometric studies estimating the relation between biodiversity and input use (costs) at farm level are rare, the exception being Peerlings and Polman (2004), who use a micro-econometric approach to analyse the joint production of milk and environmental services. The economics of Swedish pastures has previously been analysed by Kumm (2004) and Nilsson (2009). Kumm argues that incorporating adjacent forest and arable land to the pastures will decrease the cost per ha of pasture land, while Nilsson calculates the cost of providing pastures as a function of area and perimeter. Nilsson concludes that the cost of providing biodiversity differs between Swedish regions, but recommends extended research on the topic to use farm-level cost data, since he does not model the joint production between biodiversity and other outputs.

In this paper, we analyse the relationship between farm efficiency and biodiversity at regional (NUTS1), local (adjacent to farms) and farm levels. The regional and local dimensions are stressed by recent biological research that highlights the importance of the environment adjacent to farms for the development of biodiversity (Bengtsson et al., 2005; Rundlöf et al., 2008). This implies that the behaviour of farms in the neighbourhood is an important factor for farm-level output of biodiversity.

Efficiency is estimated using Data Envelopment Analysis (DEA). The DEA methodology has been widely used within agriculture; Coellli and Rao (2005) provide a literature review of cross country studies, and Bravo-Ureta et al. (2007) provide an overview of 68 DEA studies using farm level data. Swedish examples are Hansson (2007a), Hansson (2007b), Hansson and Öhlmér (2008), and Hansson (2008); see also Kumbhakar and Heshmati (1994), who use a stochastic frontier.

The efficiency estimates are used for further analysis in two ways. The first approach is in a meta-frontier framework (O'Donnell, Rao and Battese (2008)) with NUTS1 regions defining the regional frontiers. In this approach the technological differences between different regions are estimated and related to the biodiversity in these regions. Examples of DEA used for estimating meta frontiers are Ben Naceur et al. (2009) for banks and Mulwa et al. (2009) for Kenyan agriculture.

The second approach is an econometric approach where the efficiency scores are regressed on biodiversity indicators at both farm and local levels (adjacent farms) using a Tobit model. To our knowledge, this approach has not previously been used for biodiversity indicators. Explaining efficiency differences in a second stage analysis has been done in numerous studies, and several different methodologies for this have been used. The Tobit regression n has been used for agriculture in e.g. Latruffe et al. (2004), Hansson (2007a), Hansson and Ohlmér (2008).

The 266 farms in the study primarily produce milk and meat using semi-natural grazing land. Data is from the European Farm Accountancy Data Network (FADN) in 2003. The FADN data is well suited for efficiency analysis and has been used for DEA studies in agriculture in e.g. Kleinhanss et al. (2007), Fousekis, Spathis and Tsimboukas (2001), Iráizoz, Rapún and Zabaleta (2003), Oude Lansink et al. (2002), and Latruffe and Fogarasi (2009). Data on biodiversity is available in the Swedish TUVA-database, which contains biological inventories of more than 48 000 parcels of semi-natural grazing land. In each parcel vascular plants from a set of indicator species are identified together with other indicators such as the presence of water bodies, large trees, etc.

The paper continues as follows. Section 2 discusses the DEA models and the meta frontier approach used for the efficiency analysis. Section 3 presents the data used for the efficiency analysis and the results from the models. Section 4 turns to the biological indicators and describes alternative environmental indicators representing biodiversity in the analysis. In section 5 the efficiency estimates are regressed on the biodiversity indicators. Section 6 summarizes the paper.

2. The efficiency model

In this section we present DEA (subsection 2.1) and how DEA is used to estimate a meta frontier (subsection 2.2).

2.1 Data envelopment analysis

Efficiency is estimated using DEA, see e.g. Farrell (1957) or Färe, Grosskopf and Lovell (1994). The main advantage of DEA is that it is a non-parametric method that uses linear programming to construct a piece-wise frontier with the best observation s in the sample, and therefore the methodology does not require a functional form to be specified, which enables the estimation of a flexible production technology. The drawbacks are that the non-parametric method does not include a random error, and that the frontier is constructed with observations of the sample at hand. The latter is especially problematic if the best practice technology is defined by outlier observations, and thus special attention is needed for observations that define the frontier.

Policies for preserving semi-natural pastures with high biodiversity focus on the cost of providing the pastures. Therefore, we use an input oriented model in which the observed cost for a farm is compared to the minimum cost for a similar unit. The farm for comparison is constructed in the model as the linear combination of farms in the sample, producing at least the same amount of output and using equal or less inputs in the production process. The DEA model is written as

$$Eff_i = min_{z,\lambda}\, \lambda$$

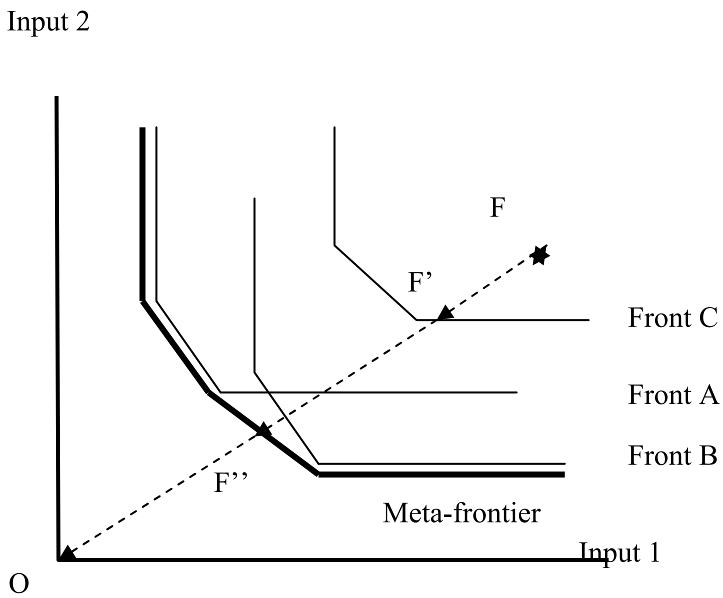
$$\begin{aligned} & s.t \\ & \sum_{k=1}^{K} z^k\, y_m^k \geq y_m^l && m = 1, \dots, M && [1] \\ & \sum_{k=1}^{K} z^k\, x_n^k \leq \lambda x_n^l && n = 1, \dots, N \\ & z^k \geq 0 \end{aligned}$$

y_m is output m, x_n is input n, l is the unit under evaluation and z is the vector of intensity variables. The model ensures that the frontier has at least as much production for each of the outputs (y) that is produced. Model 1 above is the constant return to scale (CRS) model used in this paper. CRS can be considered a long-run approach, since an inefficient scale of operation is considered as inefficiency in the model as opposed to variable returns to scale. Public policies for biodiversity are regarded as a long-run political objective, and thus we are interested in a long-run model. Following this, all of the inputs in the production process are modelled as variable.

2.2 The meta frontier

O’Donnell, Rao and Battese (2008) outline the concept of a meta frontier, show how it can be estimated using DEA and provide an empirical example using FAO agricultural statistics. The concept of a meta-frontier is used when the production environment differs between groups of units, and the topic of interest is to what extent these differences restrict the production possibilities. In this paper we use an input-oriented version of the DEA meta frontier presented in O’Donnell, Rao and Battese (2008).

Figure 1. Meta frontier



In figure 1 three groups of units, which are identified in the three frontiers A, B and C, define the technology for each of the groups. The meta frontier is the production technology defined by all units in the sample, in this case the envelopment of the A and B technologies. In figure 1, the meta frontier is represented by the bold line. In the meta-frontier approach the unit under evaluation, F in figure 1, is evaluated against the over-all frontier defined by all units in the sample, and the frontier defined by other units belonging to the same group (C). In our empirical application, these are farms located in the same region as F, which is inefficient compared to other units belonging to group C, and the efficiency score corresponds to the ratio OF’/OF ≤ 1. However, belonging to group C restricts the possibilities of minimizing costs. Evaluated against the meta-frontier, F has an efficiency score corresponding to the ratio OF’’/OF≤ OF’/OF ≤1. The difference between the meta-frontier and the C-frontier is the ratio OF’’/OF’, which is calculated from the estimated efficiency scores as OF’’/OF / OF’/OF. The difference shows how restrictive it is for the unit to produce under conditions that are specific to units belonging to group C. This is referred to as the technology ratio (TR).

3. Empirical efficiency estimation – data and results

This section presents the empirical application of the frontier estimations, with the first subsection containing the data on inputs and outputs in the agricultural production process, and the second subsection containing the empirical results of the frontier estimation.

3.1 Data

The data used in the efficiency models is from the Swedish FADN, which consists of around 1000 farms per year. Data used in this study is from 2003. Since the purpose of this study is to relate efficiency to biodiversity, the sample of farms is restricted to farms having data on biodiversity; this information is extracted from the Swedish TUVA database discussed in detail in section 4. In order to relate information from TUVA to specific farms, TUVA and FADN have been linked by using GIS and information from the Swedish farm register. Since our aim is to investigate the relationship between efficiency and biodiversity in semi-natural pastures, we focus our study on farms predominantly producing milk and beef. This leaves us with 266 farms of which 64 are in the NUTS1 region 'East Sweden', 169 in 'South Sweden' and 33 in 'North Sweden'.

We use output from animal production and "other outputs" in the DEA model. Animal production is considered a separate output since this is the main contributor to the provision of pastures. Other outputs mainly consist of crop outputs as defined in the FADN data. On the input side costs that are specific to animal production (e.g. feed) are used as a separate input. In addition to this we use hours of labour (both hired and family labour), value of capital (machinery, buildings, land (utilizable agricultural area) and breeding livestock), and other costs. Table 1 presents summary statistics of inputs and outputs for all farms in Swedish kronor (SEK).

Table 1. Outputs and inputs for DEA model. 266 farms.

Variable	Mean	Std. Dev.	Min	Max
Animal output (SEK)	977 930	1 365 987	935	1.37e+07
Other output (SEK)	543 689	770 451	18 960	7 518 495
Input for animal production (SEK)	568 836	6 63 215	16 992	7 009 009
Labour (hours)	4 464	3 145	800	27 533
Capital (SEK)	4 117 902	4 597 991	305 676	3.47e+07
Other costs (SEK)	1 005 495	1 092 521	103 551	8 265 015

The average animal output is 978 000 SEK (about 97 800 Euro), and total output from the average farm is about 1.5 million SEK. Average values for the farms in different NUTS regions are presented in Table 2.

Table 2. Mean values for inputs and outputs in Swedish NUTS1 regions

Variable	East	South	North
Animal output	878 975	1 054 172	779 393
Other output	704 489	521 847	343 689
Input animal	573 239	579 027	508 110
Labour	4 438	4 459	4 537
Capital	4 922 967	4 072 989	2 786 579
Other costs	1 114 071	998 115	832 717
No. obs.	64	169	33

Animal output is largest in South Sweden, followed by East Sweden, but, due to a larger share of other output, the farms in East Sweden have in total approximately the same output as the farms in South Sweden. The farms in North Sweden are smaller, with respect to both animal output and total output.

3.2 Efficiency results

Technical efficiency evaluated against the common national (meta) frontier is presented in Table 3. The results are for both the pooled sample containing all farms and for farms in the different NUTS1 regions (still evaluated against the national frontier).

Table 3. Technical efficiency (CRS) evaluated against the national meta-frontier

Variable	Obs	Mean	Std. Dev.	Min	Max
All units	266	0.738	0.196	0.225	1
East	64	0.782	0.185	0.325	1
South	169	0.738	0.201	0.225	1
North	33	0.652	0.160	0.269	1

In total the 266 farms in the sample have an average efficiency score of 0.74 implying that if the national frontier represents the true technology frontier, they should be able to reduce input use by about 26 % without decreasing outputs. However, the average efficiency score differs for the three regions. In Eastern Sweden the average is 0.78, in South Sweden 0.74, and in Northern Sweden 0.65. A Wilcoxon-Mann-Whitney test shows that farms located in the different regions differ from each other significantly. The distribution of the efficiency scores for each region is presented in a Salter diagram in figure 2.

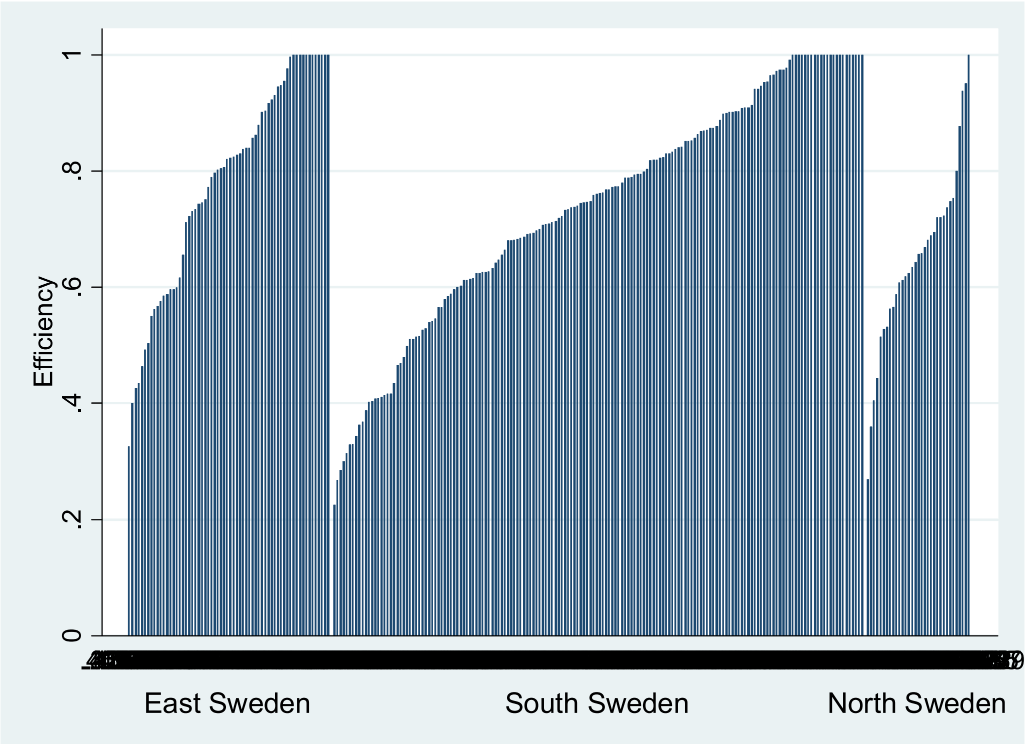


Figure 2. Efficiency scores by region estimated against the national meta-frontier.

Differences in average efficiency between the regions might be due to different production possibilities and thus not a result of inefficient use of resources at the farm level. This is analyzed in the meta-frontier framework discussed above. The technology ratio for the regions is presented in Table 4.

Table 4. Technology ratio for NUTS1 regions.

Region	Mean	Std. Dev.	Min	Max
East	0.951	0.058	0.760	1
South	0.981	0.022	0.900	1
North	0.756	0.146	0.335	1

Apparent from Table 4 is that both South and East are close to the national frontier compared to the North farms. A Wilcoxon-Mann-Whitney test shows that there is a significant difference between the technology scores for northern farms and farms in the other regions. Interestingly, the farms in East Sweden, despite having a somewhat lower technology ratio, are *on average* more efficient compared to the meta-frontier than the farms in South Sweden.

4. Environmental indicators

In this section the biodiversity indicators are discussed with focus on vascular plants. Other groups of plants, as well as animal species, are excluded from the analysis. These species are not systematically sampled in the TUVA database. The TUVA database does not contain red listed species, but more common species that indicate the presence of high biodiversity. Thus, we do not explicitly model rare species, and it may be argued that rare species should be protected by nature reserves and not by general agricultural policies. In the analysis, we take a national perspective on biodiversity by relating the species to objectives at a national level. Of course, regional as well as global dimensions of biodiversity are also important, but this falls outside the scope of this analysis.

4.1 Environmental quality indicators

Biodiversity is defined as the number of species present in the pastures provided by the farmers. However, following Waldo et al. (2009), all species are not defined as increasing the biodiversity, as they indicate e.g. fertilizing, which will reduce biodiversity in the long run. These species are denoted negative indicator species as opposed to the positive indicator species used as indicators of biodiversity.

Denoting the representation of a positive indicator species in pasture *p* by *R* (i.e. R is a dummy variable taking the value 1 if the species is represented and 0 otherwise), a first indicator of biodiversity (I_1^p) would be

$$I_1^p = \sum_j^J R_j \qquad p = 1...P \qquad [2]$$

Where *j* is the species, *J* is the total number of species, and *p* represents pastures.

The number of positive indicator species will be our base indicator for biodiversity. However, I_1^p can be viewed as a special case of a *biological benefit function* as specified by e.g. Arponen et al. (2005), Moilanen (2007), and van Teeffelen et al. (2008). In a biological benefit function the benefits received from a species depend on its value, in the literature often operationalized as a function of how rare the species is. We use this approach, although the value of a species from an economic point of view would be based on society's utility from the species rather than rarity. Such estimates are outside the scope of this stydy. An indicator, I_2^p , for the biological benefits received from a pasture might then be expressed as

$$I_2^p = \sum_j w_j R_j \qquad p = 1...P \qquad [3]$$

where w_j is the specific weight of a species depending on how valuable it is to society. As weight, *w*, in the empirical estimations will be used as the inverse of the number of representations in the sample, i.e. $w_j = \frac{1}{\sum_1^P R_j}$. Species present in many pastures, i.e. commonly found species, will have a low weight and thus add less to the biodiversity indicator than more rare species. Of course, this is a value judgment and alternative ways of determining w are available. Arponen et al. (2005) use the red-listing and regional rarity as a base for determining w where rarer species get a higher weight. This approach is not used in our case since the indicator species do not represent rare species, but rather habitats for such species.

4.2 Biodiversity in the TUVA Database

The TUVA database

The TUVA inventory (Swedish Board of Agriculture, 2005a; 2005b) consists of Swedish agricultural land that is used for semi-natural grazing and contains substantial environmental or cultural values. Data was collected from 2002 to 2004 for over 300 000 ha of land. Of this, 270 000 ha of semi-natural grazing land were classified as valuable, whilst the remaining 31 000 ha were not included in further analysis. In total a full inventory was performed for 48 527 different parcels of land. All land is divided into categories based on Natura2000 types of nature. In all 33 different kinds of Natura2000 types of nature were identified. Of the 48 527 pastures in the TUVA database 15 712 have only one type of nature, while 31 968 have more than one (847 pastures did not have type of nature defined).

Focus in the TUVA database is on the presence of vascular plants. In total about 420 000 vascular plants were registered in the field studies. The most common is Lady's Bedstraw (*Galium Verum*) which is present in more than 20 000 pastures. In total 69 species of vascular plants were systematically collected. 60 of these are indicators of high quality, while the remaining 9 are indicators of low quality. An example of the latter is the Stinging nettle (*Urtica dioica*), which is favoured by fertilizers. Fertilizers (and Stinging nettles) are disadvantageous for species dependent on continuously grazed lands.

Biodiversity Indicators

From the TUVA database the biodiversity indicators I_1^p and I_2^p have been calculated for each pasture. Table 5 contains the summary statistics for the indicators.

Table 5. Summary statistics for biodiversity indicators per parcel

	Mean	St. dev.	Min	Max
I_1^p	6.844	4.408	0	32
I_2^p	0.001	0.002	0	0.031
Obs = 48 527				

The number of species in the sample varies between 0 and 32, with an average of 6.8 species present in a pasture. The weighted biodiversity varies between 0 and 0.03 with an average of 0.001.

4.3 Adjusting the indicators for external environment

The biodiversity present in a pasture is partly due to natural conditions and partly due to farming efforts. Using information on natural conditions and geographical locations, it is possible to purge out the effect of differences in a number of factors outside the control of the farmer. This is done in a regression model as

$$I_1^p = \alpha + \beta X + \varepsilon, \ \ \mathrm{j} = 1{,}2 \qquad [4]$$

where *I* is the biodiversity indicator and *X* represents variables that affect biodiversity but are outside the control of the farmer. In the equation, ε is interpreted as the individual pasture's deviation from the expected biodiversity as predicted by the exogenous variables. Pastures that are well managed from a biodiversity perspective are expected to have a positive ε, while less well managed pastures are expected to have a negative value. As exogenous variables in the X matrix we use variables representing different types of nature as defined by Natura2000. The influence from *type of nature* is operationalized as 33 dummy variables indicating if the Natura2000 nature type is present in the pasture or not. Pastures with more nature types are expected to have more species present, since they have a greater variability in natural conditions. The total pasture *area* is included as well.

A second natural condition that might affect the biodiversity is the *coverage with trees and bushes*. A large share of the pastures that are shaded during part of the day will affect the flora, and so will the edge of a forest forming part of the environment closest to the pasture. This effect is operationalized as a dummy for the pasture located at the edge of a forest, a variable representing the share of the pasture shaded by trees, and a variable representing the share of the pasture shaded by bushes.

The *geographical location* is included as a set of 23 dummy variables indicating the county where the pasture is located. Sweden is a geographically large country and different counties might differ widely in climate, soil properties etc. The county of Stockholm is dropped from the equation in order to avoid multicollinearity and is thus considered as the reference county.

The presence of different kinds of *water* in the pastures is included to explain differences in the biodiversity that is due to humidity in the soil. Ten variables describing waters such as marine and fresh water beaches, creeks, ponds, marshes, etc. are included as dummy variables. In addition, the number of different kinds of water is included as well.

The models are estimated using ordinary least squares (OLS). We assume a log-linear relationship following e.g. Brady and Kellermann (2005). Approximately 39 % of the variability in the number of observed positive signal species (I_1^p) can be explained by differences in the exogenous variables. Worth noting is that most variables are significant, indicating that both type of nature and geographical location explain differences in biodiversity. Shading by trees and bushes is also significant, while most water-related variables are not.

Approximately 33 % of the variation in the I_2^p indicator can be explained by exogenous factors. Note that most variables are significant, indicating that both type of nature and geographical location are significant for biodiversity. Shading by trees and bushes and most water-related variables are also significant.

We define adjusted indicators for both I_1^p and I_2^p which simply are the residuals in the regression models. Thus, they consist of the variation in biodiversity that cannot be explained by differences in the natural conditions. The estimation results and the distribution of the adjusted indicator are shown in Annex 3. Summary statistics are presented in Table 6 below.

Table 6 Summary statistics for adjusted environmental indicators

Variable	Obs	Mean	Std. Dev.	Min	Max
I_1^p adjusted	48 527	7.21e-11	0.509	-2.820	1.750
I_2^p adjusted	48 527	1.74e-14	0.001	-0.007	0.025

The different indicators to some extent reflect different dimensions of biodiversity, but they are of course still expected to be positively correlated – i.e. if a pasture is defined as having high biodiversity by one indicator, it should not be defined as having low biodiversity by another. Table 7 below shows the correlation matrix for the indicators.

Table 7. Correlations between environmental quality indicators

	I_1^p	I_2^p	I_1^p adj	I_2^p adj
I_1^p	1.0000			
I_2^p	0.5791	1.0000		
I_1^p adjusted	0.6588	0.3536	1.0000	
I_2^p adjusted	0.4117	0.8146	0.4359	1.0000

Indicators I_1^p and I_2^p have a correlation of 0.58. That they are positively correlated is of course a result of I_2^p being the weighted sum and I_1^p being the unweighted sum. I_1^p has a correlation of 0.65 with the adjusted measure. The I_2^p variable has a correlation of 0.81 with the adjusted measure, indicating that the adjustment makes a smaller difference for I_2^p compared to I_1^p.

4.4 Other biodiversity indicators

In addition to the biodiversity indicators for vascular plants, two indicators for water and large trees are included in the model. Although vascular plants are in focus for measuring biodiversity in the pastures, a rich diversity of other species is important as well. Large trees are often inhabited by a large number of insects, and so are many smaller waters – especially when they are too small to keep a fish population. Summary statistics for the indicators are presented in Table 8 below.

Table 8. Other biodiversity indicators per parcel

Variable	Obs	Mean	St. Dev.	Min	Max
No. of water types	48 527	0.538	0.818	0	7
No. of large trees	48 527	0.500	3.003	0	171

The number of types of water is the same variable as presented in Annex 1 and differs between 0 and 7 types. The number of large trees is the number of trees more than 1 meter (m) in diameter below chest height. This varies from 0 to 171 trees. The correlation between the two additional indicators and I_1^p, I_2^p, I_1^p adjusted, and I_2^p adjusted is in general low. The largest is a correlation of 0.25 between number of water types and I_1^p. A low correlation between water and the adjusted biodiversity indicators is expected since water is included as an explanatory variable in the regression models performed for adjusting I_1^p and I_2^p.

5. Efficiency and the provision of biodiversity

5.1 Regional differences in biodiversity

NUTS regions

An important aspect of the regional flora in Sweden is the north-south dimension. Swedish pastures in the north face a considerably colder climate, which is an advantage for some species but a disadvantage for others. In Table 9 we show how many species are present in the three regions and to what extent the regions contribute to the conservation of the species at the national level.

Table 9. Number of species in NUTS1 regions (from TUVA).

		Number of species where >X% of the locations are within the NUTS1 region		
	No. Species	No. > 90 %	No. > 50%	No. < 10 %
East	58	0	4	17
South	60	9	41	2
North	56	2	5	42

Table 9 is interpreted as follows. In the TUVA database each species is observed as growing in a large number of parcels of land. 60 different species are observed as growing in at least one parcel of land in South Sweden. For 9 of these species more than 90 % of the parcels they grow in are located in South Sweden. 41 species have more than 50 % located in South Sweden, and 2 species have less than 10 %. For East, 58 different species are found in the TUVA inventory. Of these 4 species have more than 50 % of their locations in this region, none have more than 90 %, and 17 of the species have less than 10 %. For North, 2 species have more than 90 % of their locations in this region, 5 more than 50 % and 42 have less than 10 %.

Both South and North have species that are located only, or to a very large extent, solely within the region. This reflects the north-south dimension. East is to some extent located between South and North, and thus some North species will have their southern boundary, and some South species will have their northern boundary, in East region.

Comparing the regional distribution of species with the regional frontiers, it is obvious that the disadvantage of farming in North Sweden will affect 7 out of 60 TUVA-species to a larger extent. For two of these species (Alpine Cat's-tail (*Phleum alpinum*) and Lesser Clubmoss (*Selaginella selaginoides*) the northern pastures are very important for the presence of these species in the agricultural landscape.

5.2 Empirical assessment

Section 3.2 and 5.1 show the geographical pattern for efficiency and biodiversity. However, the NUTS1 level is too large to study effects of local surroundings and the potential spread of species to and from adjacent fields. This is further analysed in a Tobit model relating biodiversity at the individual farm as well as in the local surrounding of the farm to farm-specific efficiency.

The Tobit approach has been criticized and several alternative approaches have been applied. Simar and Wilson (2007) propose a bootstrapping method, which has been applied to agriculture by Olson and Vu (2009). Nonetheless, Afonso and St. Aubyn (2006) find that the bootstrapped and Tobit approach give similar results in their study of efficiency in education.

The Tobit model is commonly used for the second stage analysis since the DEA scores always are less or equal to one. However, a number of alternative models have been used in the literature. McDonald (2009) proposes an OLS methodology, while e.g. Bojnec and Latruffe (2009) use a truncated regression model. Some authors use non-parametric methods, e.g. Gaspar et al. (2009) using a Kruskal-Wallis test to compare efficiency scores between groups of Spanish farms, and Kleinhanss et al. (2007) who use a non-parametric regression. We use a Tobit model following e.g. Latruffe et al. (2004) and Hansson (2007a) who have used the model for agricultural data, and Hoff (2007) who tests four different models (including OLS) and concludes that the Tobit model in most cases is sufficient for representing second stage DEA models.

The explanatory variables in the regressions are discussed below. Observe that we now turn to farm level, while section 4 concerns parcels. The superscript *f* will be used to indicate that biodiversity indicators are calculated at farm level.

Biodiversity indicators

Our main indicator of biodiversity is I_1^f , the number of TUVA species on farm level. All 48 527 parcels of land in the TUVA database have been linked to individual farms by means of a database of all Swedish agricultural blocks and the Swedish farm register of 2003. Hence, we may identify the location of each farm with valuable pastures and the environmental services provided by each farm. These farms add up to almost 20 000, while around 40 000 have no valuable pasture in the TUVA database. We also use this information on all valuable pastures to calculate the provision of biodiversity in the neighbourhood of each farm, thereby capturing the influence of the local environment on each farm. Neighbouring farms are defined as those sharing a border (i.e. when the land area of two farmers is adjoined), and the surrounding biodiversity is calculated as the average biodiversity provided by each farmer's neighbour and the neighbours' neighbour (i.e. the spatial queen weight matrix of the second order).[1] Although the provision of biodiversity on farm level is correlated with the average provision of neighbours, the

[1] We have also used distance as a demarcation of neighbours (such as all farms within a radius of 30 km) but the results are similar.

correlation is found to be rather low (0.55 and 0.41 within the final sample for I_1^f and I_2^f, respectively).

In addition to the main indicator we use the alternative measures for biodiversity; the number of large trees, and the number of different types of water bodies present in the pasture. These variables are included in the regression model together with I_1^f, I_1^f adjusted, and I_2^f.

Non-biodiversity variables

From the results in section 5.1 we find regional differences between farms, and regional patterns are found for Swedish agriculture in Hansson (2007a) as well. To control for regional differences in the regressions, we include the NUTS1 regions as dummy variables. Farm specialization might affect efficiency, and to control for this we use the share of animal production in the output, following e.g. Fousekis et al. (2001). Bojnec and Latruffe (2009) employ a similar approach using a herfindahl index to describe farm specialization. We use standardised work hours as a representation for farm size[1] and a dummy indicating whether the farm has ecological production or not, since the importance of organic production for the provision of biodiversity has been underscored by Bengtsson et al. (2005) and Fuller et al. (2005). Still, organic farming may also indicate lower productivity, which was found in Oude Lansink et al. (2002) as well as in Kleinhanss et al. (2007). Summary statistics for the explanatory variables are presented in Table 10.

Table 10. Summary statistics for explanatory variables. Farm level.

Variable	Definition	Mean	Std. Dev.
East	Dummy (1 if observation in East Sweden)	0.24	0.43
North	Dummy (1 if observation in North Sweden)	0.12	0.33
I_1^f	Farm level provision of biodiversity[1] (as defined in section 4.1)	7.42	4.64
I_2^f	Farm level provision of biodiversity[1] weighted by species rarity (as defined in section 4.1)	0.0014	0.0016
I_1^f **adjusted**	Farm level of provision of biodiversity[1], adjusted for external environment (as defined in section 4.3)	-0.01	0.46
Trees	Farm level indicator of valuable trees (alternative biodiversity measure)	0.65	1.93
Water bodies	Farm level indicator of valuable water bodies (alternative biodiversity measure)	0.66	0.81
I_1^f **_landscape**	Average provision of I_1^f by neighbouring farms.	3.89	2.98

[1] A standardised work hour is defined by the Board of Agriculture, and it depends on the total land area and total number of animals on the farm as well as on the distribution between different crops and animals.

I_2^f _landscape	Average provision of I_2^f by neighbouring farms.	0.0009	0.0011
I_1^f adj_landsc	Average provision of I_1^f _adj by neighbouring farms.	0.004	0.11
Share animal	Animal output, share of total output.	0.59	0.24
Standard hour	Standardised hours on farm based on the calculations of the Swedish Board of Agriculture.	3.84	2.41
Organic	Dummy (1 if observation is organic)	0.33	0.47

1. Average over the farm's I^p for farms with more than one pasture containing TUVA information

Results

Table 11 presents the results of a Tobit regression for the pooled sample (meta frontier) containing all 266 observations when we use the benchmark measure of biodiversity (i.e. I_1^f). If we start with the benchmark specification in regression (1) in Table 11, we can see that all coefficients but one are precisely estimated. The exception is the provision of biodiversity at farm level. The other variables are in line with our expectations. For example, we find the most efficient milk and beef producers in East Sweden, while the least efficient are found in North Sweden. Geographical differences are found also in other studies of Swedish farm efficiency, se Hansson (2007a). We also find that both specialised (i.e. those with a higher share of animal output) and larger producers (higher values of standardised hours) are more efficient although the positive effect of being large decreases with size. Finally, we find that organic farms are less efficient, which is in line with Oude Lansink et al. (2002) and Kleinhanss et al. (2007).

If we exclude the farm-level provision of biodiversity and include the average provision of biodiversity on neighbouring farms, then the fit of the model increases and we can see (regression 2 in Table 11) that farms in areas with a high degree of biodiversity are less efficient. This result is robust for the inclusion of the farm-level biodiversity measures (regression 3) as well as alternative measures (regression 4). The only difference that appears when we include more variables is that the alternative indicator, valuable trees, is significant. The negative relationship implies that farms with valuable trees are more likely to be less efficient than farms without. We have experimented with regional specific coefficients by interacting the provision of biodiversity, by both the observed farm and neighbours, with regional dummies. The only difference compared to the results in Table 11 is that the negative relationship between efficiency and neighbours' provision of biodiversity disappeared for producers in North Sweden. Hence the negative relationship is mostly robust in South and East Sweden. Further, we have substituted the biological benefit function (I_2^f) for the number of species (I_1^f) in order to assess whether the rarity of species influences the results. However, the relationships and significance levels are similar, and hence we do not present the results but they are available upon request. Finally, we have substituted the number of species adjusted for external environment (I_1^f _adj) for the number of species (I_1^f) as presented in annex 2. The non-biodiversity variables are robust for the change, but the biodiversity indicator turns insignificant. Thus, taking out the effects of soil properties, shading from bushes, etc. from the biodiversity indicator, we find no relationship between efficiency and biodiversity, which underscores the importance of the surrounding environment for high biodiversity. From the results in Table 11 we know that farms located in areas with high biodiversity are less efficient (even if this might be caused by environmental conditions) and environmental support will contribute to the long-term survival of farming in these regions.

Table 11. Tobit results with efficiency evaluated against national (meta) frontier as dependent variable.

Variable	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)
	(1)	(2)	(3)	(4)
East	0.06 (*.04*)	0.06 (*.02*)	0.06 (*.04*)	0.06 (*.03*)
North	-0.08 (*.00*)	-0.11 (*.00*)	-0.10 (*.00*)	-0.11 (*.00*)
I_1^f	-0.001 (*.81*)		0.004 (*.21*)	0.004 (*.24*)
Trees				-0.01 (*.01*)
Water bodies				0.001 (*.96*)
I_1^f **landscape**		-0.01 (*.00*)	-0.01 (*.00*)	-0.01 (*.00*)
Share animal	0.20 (*.00*)	0.20 (*.00*)	0.20 (*.00*)	0.17 (*.00*)
Standard hour	$7e^{-5}$ (*.00*)	$7e^{-5}$ (*.00*)	$7e^{-5}$ (*.00*)	$7e^{-5}$ (*.00*)
Standard hour^2	$-2e^{-9}$ (*.00*)	$-2e^{-9}$ (*.00*)	$-2e^{-9}$ (*.00*)	$-2e^{-9}$ (*.00*)
Organic	-0.07 (*.00*)	-0.07 (*.00*)	-0.07 (*.00*)	-0.06 (*.00*)
Constant	0.45 (*.00*)	0.45 (*.00*)	0.44 (*.00*)	0.46 (*.00*)
/sigma[b]	.17 {.008}	.17 {.008}	.17 {.008}	.17 {.008}
Pseudo R2	3.08	3.26	3.31	3.41

Notes: [a] All p-values within parentheses are based on robust standard errors. [b] Figures within curly brackets are standard errors.

6. Summary

The conservation of agricultural landscapes is an explicit environmental objective in Sweden. The provision of landscape services in addition to commercial products is assumed to be costly for the farmer but valuable for society. The latter is true, not least for biodiversity, since about 40 % of Swedish red listed species are present in the agricultural landscape. In this study we evaluate if farms with high biodiversity are less efficient producers than farms with low biodiversity. The focus is on the provision of biodiversity-rich pastures, which are dependent on grazing animals for the long-term development of plant species.

Data on biodiversity is from the TUVA database, which is a biological survey of important plant species in Swedish semi-natural pastures. The data contains biological information for more than 48 000 parcels of land. In this paper, we use species of vascular plants, large trees, and water bodies as indicators of biodiversity. The number of vascular plants is the main indicator since the presence of vascular plants indicates well managed pastures. As the focus is on pastures, the economic analysis involves farms which produce animal outputs using grazing animals. Economic data is from the FADN data base, and in total we have 266 farms for which both economic and biological information is available in 2003.

Efficiency is estimated using DEA and the efficiency scores are related to biodiversity in a second stage Tobit regression. The main result is that the number of vascular plant species in the landscape surrounding the farm has a negative correlation with farm efficiency, and that the number of vascular plants at the farm level is not related to efficiency. This might be explained by differences in e.g. soil and landscape properties that influence both efficiency and biodiversity. The importance of the locality is strengthened by the lack of any significant correlation between efficiency and biodiversity when landscape properties are controlled for. In addition, the negative relationship between efficiency and biodiversity is more robust in South and East Sweden.

To elaborate on the regional dimension, efficiency scores and technology ratios are estimated, using a meta-frontier framework, for NUTS1 regions. The Swedish NUTS1 regions are large and located in a north-south dimension. The further south in the country, the milder the climate. According to the meta-frontier analysis, southern regions have a more favourable production environment than northern regions, and they contain more plant species as well. Only two (out of 60) plant species are primarily dependent (have more than 90 % of their locations) on the northern agricultural landscapes.

The results emphasise the regional and local dimensions of the provision of biodiversity. Few species are dependent on the northern farms and the relationship between efficiency and biodiversity is weak in this region. In the eastern and southern parts of the country there is a negative relation between farm efficiency and biodiversity in the local landscape. Since inefficient farms are less competitive, society faces a risk that farming with high biodiversity output will decline.

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Annex 1: Adjusted biodiversity indicator (I_1^f) - OLS

The OLS regression results using log of I_1^p as dependent variable is presented below.

Table A1 OLS regression with log of I_1^p as dependent variable, adjusted R2 = 0.3927

Variable name	Parameter	P-value	Variable name	Parameter	P-value
Nature type					
D_1310	-0.7960	0.0000	**County**		
D_1330	-0.7387	0.0000	lan_Ac	-0.4685	0.0000
D_1630	-0.8078	0.0000	lan_Bd	-0.4992	0.0000
D_2130	-0.6870	0.0000	lan_S	-0.2215	0.0000
D_2320	-1.0124	0.0050	lan_W	-0.3200	0.0000
D_2330	-0.8858	0.0000	lan_X	-0.5195	0.0000
D_4010	-0.7724	0.0000	lan_Y	-0.3678	0.0000
D_4030	-0.6731	0.0000	lan_Z	-0.1964	0.0000
D_4060	-1.4421	0.0000	lan_C	-0.1634	0.0000
D_5130	-0.6697	0.0000	lan_D	-0.0979	0.0000
D_6110	-0.8333	0.0000	lan_E	0.0417	0.0170
D_6120	-0.6576	0.0000	lan_T	-0.0633	0.0030
D_6150	-0.1903	0.3830	lan_U	-0.1132	0.0000
D_6170	-1.1001	0.0320	lan_F	0.0029	0.8740
D_6210	-0.3945	0.0000	lan_G	-0.4404	0.0000
D_6230	-0.6194	0.0000	lan_H	-0.2332	0.0000
D_6270	-0.4082	0.0000	lan_I	-0.0494	0.0150
D_6280	-0.7044	0.0000	lan_K	-0.3736	0.0000
D_6410	-0.8307	0.0000	lan_M	-0.6703	0.0000
D_6430	-0.7310	0.0000	lan_N	-0.4222	0.0000
D_6450	-1.0362	0.0000	lan_O	-0.3756	0.0000
D_6510	-0.1968	0.0000	**Water**		
D_6520	-0.2807	0.0000	Temporarily flooded	-0.0112	0.9180
D_6530	-0.4637	0.0000	Bog	-0.1170	0.2870
D_7140	-0.7414	0.0000	Ground water impact	0.0226	0.8350
D_7160	-0.8237	0.0240	Marsh	0.0003	0.9980
D_7220	-0.7797	0.0000	Wet rock	-0.0385	0.7240
D_7230	-0.5912	0.0000	Creek	-0.1031	0.3430
D_8230	-0.8837	0.0000	Beach marine	-0.0810	0.0000
D_8240	-0.8008	0.0000	Beach fresh water	-0.2076	0.0000
D_9070	-0.8920	0.0000	Water and limestone	0.0902	0.0000
Other nature type	-0.8645	0.0000	Pond <1ha	-0.0883	0.4170
Cultivated fodder	-0.9185	0.0000	No. of water types	0.0936	0.2190
Trees/bushes			No. of water types sq	0.1078	0.3550

Forest edge	0.0627	0.0000	**Other**		
Shadow-trees	0.1001	0.0000	No. of nature types	-0.2234	0.0000
Shadow-tees sq[1]	0.0359	0.0010	No. of nature types sq	1.4407	0.0000
Shadow - bushes	-0.0283	0.0000	Area	0.0818	0.0000
Shadow - bushes sq	-0.0090	0.0140	Area sq	-0.0029	0.0100
			Constant	1.9099	0.0000

1 Sq represents the squared value

Annex 2: Tobit model using the adjusted biodiversity indicator

Table A2 Tobit results with efficiency evaluated against national (meta) frontier as dependent variable.

Variable	Coef.	Std. Err.	t	P>t
East	0.058	0.028	2.05	0.042
North	-0.082	0.030	-2.74	0.007
I_1^p **_adj**	0.006	0.024	0.25	0.804
Trees	-0.009	0.005	-1.74	0.083
Water bodies	-0.001	0.014	-0.04	0.970
I_1^p **adj landscape**	0.043	0.091	0.48	0.630
Share animal	0.180	0.053	3.38	0.001
Standard hour	0.079	0.013	6.12	0.000
Standard hour^2	-0.002	0.001	-2.96	0.003
Organic	-0.067	0.024	-2.85	0.005
Constant	0.413	0.051	8.08	0.000
/sigma	0.170	0.009		
Pseudo R2	3.1567			

Based on robust standard errors.

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