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AN EXAMINATION OF THE IMPACT OF AGRI-ENVIRONMENTAL POLICIES AND INTENSIFICATION ON THE HYPERBOLIC EFFICIENCY OF DUTCH DAIRY FARMS

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Abstract

The intensification of the dairy sector and the associated detrimental impacts on the environment has geared agri-environmental policies towards fulfilling environmental objectives. This study examines the impact of such policies and intensification on the hyperbolic efficiency of Dutch dairy farms which provides a measure for their joint technical and environmental performance. The results indicate that the introduction of decoupled payments reduced the hyperbolic efficiency of farms highlighting greater losses in technical than environmental performance, while agri-environmental subsidies have no impact on our efficiency measure. Finally, intensification increases hyperbolic efficiency implying that under appropriate nutrient-management practices, intensification can be sustainable.

Key words: intensification, agri-environmental policies, hyperbolic efficiency, Dutch dairy farms

1. Introduction

To abate the negative impact of intensification on the environment, policy makers in most European countries implemented policies specifically aiming at reducing the amount of nutrient leaching in the dairy sector. These policies usually take the form of incentives that either partially internalize the negative externalities of nutrient leaching or provide rewards for reduced leaching and application of environmentally friendly production techniques. In the Netherlands, the Mineral Accounting System (MINAS) came into force in 1998, using a farm gate balance approach to measure the N and P that enter and leave the farm (i.e. nutrient surplus¹). In 2006, the Application Standards Policy (ASP) replaced MINAS setting application standards for Nitrogen (N) and Phosphorus (P). The Dutch dairy sector was also influenced by several EU agri-environmental policies. Input-related subsidies and livestock subsidies provided rewards to farmers who respect standards related to fertilizer use and minimization of the leaching of nutrients. Decoupled payments, introduced in 2006, obliged farmers to maintain their land in good agricultural and environmental condition in order to receive them. Hence, all the above-mentioned policy instruments are expected to improve the environmental performance of dairy farms by enhancing their ability to reduce nutrient surpluses.

The nature of these policies may also imply that the technical performance of the farms is affected. Zhu et al. (2012) identified that input-related and livestock subsidies were negatively related with technical efficiency because of imposing constraints on input use. Additionally, Emvalomatis et al. (2008) and Zhu and Oude Lansink (2010), concluded that decoupled payments are negatively related with technical efficiency, attributing this effect on possible reduction in farmers' motivation to improve the efficiency of their farms. Concerning intensification, Reinhard et al. (1999) found that intensification is positively related with both technical and environmental performance of farms. However, when coming to policy evaluation, empirical studies have focused on the policies effect merely on a single efficiency measure. To be able to assess the impact of such policies on both performance measures simultaneously, a measure needs to be available of the ability of the farm to efficiently produce outputs given the inputs used, as well as, with the minimum undesirable effect on the environment.

A hyperbolic efficiency measure considers the possibility of both expanding outputs and contracting inputs simultaneously. For the undesirable outputs such as nutrient surplus, a farm has an incentive to contract it, and the amount of possible contraction can be used as a measure of environmental performance. Therefore, hyperbolic efficiency can serve the

¹ Nutrient surplus is determined as the difference between the nutrients found in the inputs and the nutrients found in the outputs.

purpose of measuring the joint technical and environmental performance of farms. Hence, this paper addresses the impact of intensification and policies on the hyperbolic efficiency of Dutch dairy farms. Additionally, since some of these policies have opposite effects on technical and environmental efficiency we will be able to identify whether any of these effects dominate when taking into account a joint performance measure.

2. Methodology

As mentioned before, hyperbolic efficiency allows farms to follow a hyperbolic path towards their frontier giving them the possibility to expand desirable outputs and contract undesirable outputs simultaneously. Figure 1 illustrates such a hyperbolic path towards the frontier.

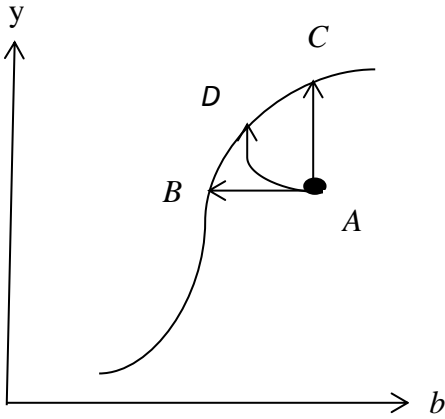


Figure 1. Hyperbolic path of an inefficient farm towards the frontier.

For the sake of simplicity, let us assume that an inefficient farm operating at point A, produces a single desirable output (y) and a single undesirable output (b). In the case that the farm seeks to expand only y keeping b fixed, it will move to point C (technical efficiency case). On the contrary, if the farm aims to contract b keeping y fixed, it will move to point B. Finally, in the case of hyperbolic efficiency, the farm seeks to equiproportionately expand y and contract b , respectively, moving hyperbolically towards point D.

A hyperbolic distance function is used to measure the hyperbolic efficiency of farms in the case where input vectors $x \in R_+^Q$ can produce desirable output vectors $y \in R_+^K$ and undesirable output vectors $b \in R_+^M$. Following Cuesta et al. (2009), the hyperbolic distance function represents the maximum expansion of the desirable output vector and the equiproportionate contraction of the undesirable output vector, given the amount of inputs used, in the following way:

$$D_H(x, y, b) = \min\{\vartheta > 0(x, y/\vartheta, b\vartheta)\} \quad (1)$$

The hyperbolic distance function has a range between zero and one, is almost homogeneous² of degrees 0, 1, -1 and 1, non-decreasing in desirable outputs and non-increasing in undesirable outputs and inputs. Using the almost homogeneity condition and choosing the K^{th} desirable output for normalization purposes $\varphi = 1/y_k$ we have:

$$D_H(x, y/y_k, by_k) = D_H(x, y, b)/y_k \quad (2)$$

² A function $f(x, y, b)$ is almost homogeneous of degrees $\lambda_1, \lambda_2, \lambda_3$ and λ_4 if $f(\mu^{\lambda_1}x, \mu^{\lambda_2}y, \mu^{\lambda_3}b) = \mu^{\lambda_4}f(x, y, b)$ for every scalar $\mu > 0$.

Parametrically, the hyperbolic distance function is specified as translog in inputs, desirable and undesirable outputs and time. Substituting the translog function into equation (2) and rearranging the terms leads to the estimable form of the distance function:

$$\begin{aligned}
-\log y_{it}^K = & a_0 + \sum_{q=1}^Q \beta_q \log x_{it}^q + \sum_{m=1}^M \gamma_m \log [b_{it}^m]^* + \sum_{k=1}^{K-1} \delta_k \log [y_{it}^k]^* \\
& + 1/2 \sum_{q=1}^Q \sum_{r=1}^Q \zeta_{qr} \log x_{it}^q \log x_{it}^r + 1/2 \sum_{m=1}^M \sum_{n=1}^N \eta_{mn} \log [b_{it}^m]^* \log [b_{it}^n]^* \\
& + 1/2 \sum_{k=1}^{K-1} \sum_{l=1}^{K-1} \xi_{kl} \log [y_{it}^k]^* \log [y_{it}^l]^* + \sum_{q=1}^Q \sum_{m=1}^M \pi_{qm} \log x_{it}^q \log [b_{it}^m]^* \\
& + \sum_{q=1}^Q \sum_{k=1}^{K-1} \rho_{qk} \log x_{it}^q \log [y_{it}^k]^* + \sum_{m=1}^M \sum_{k=1}^{K-1} \tau_{mk} \log [b_{it}^m]^* \log [y_{it}^k]^* + t \\
& + t^2 + \sum_{q=1}^Q v_q t \cdot \log x_{it}^q + \sum_{m=1}^M \psi_m t \cdot \log [b_{it}^m]^* + \sum_{k=1}^{K-1} \omega_k t \cdot \log [y_{it}^k]^* \\
& + v_{it} + u_{it}
\end{aligned} \tag{3}$$

where $[y_{it}^k]^* = y_{it}^k / y_{it}^K$ and $[b_{it}^m]^* = b_{it}^m \cdot y_{it}^K$.

The two error components are assumed to follow the following distributions: $v_{it} \sim N^+(0, \sigma_v^2)$ and $u_{it} \sim N^+(z_{it}'\xi, \sigma_u^2)$. The inefficiency component u_{it} is a function of a set of explanatory variables including farm-specific characteristics and policy variables z_{it}' , and ξ are parameters to be estimated. Considering that $\varepsilon_{it} = v_{it} + u_{it}$, the hyperbolic efficiency of farm i in time t is estimated as:

$$HE_{it} = E[\exp(-u_{it}) \mid \varepsilon_{it}] \tag{4}$$

3. Data

The data used for this application are provided by the Agricultural Economics Research Institute of the Netherlands (LEI). Table 1 presents summary statistics of the variables in equation (3).

Table 1. Summary statistics of the model's variables.

Variable	Obs.	Mean	Std. Dev.
Milk (1000€)	2105	216.84	142.39
Other (1000€)	2105	24.19	22.09
K (1000€)	2105	16.18	11.09
L (1000 man-hours)	2105	3.1	1.35
A (hectares)	2105	56.04	34.35
I (1000€)	2105	59.76	43.28
S (livestock units)	2105	153.57	93.98
N (1000kg)	2105	9.11	6.74
P (1000kg)	2105	0.58	0.69

Deflated revenues from sales of cow's milk (milk), and, deflated revenues and change in value of beef and veal, plus deflated revenues from sales of other products (other) are specified as desirable outputs. Five inputs are used in the translog specification: capital (K), labor (L), agricultural area (A), variable inputs (I) and livestock units (S). Finally, N and P surpluses are specified as undesirable outputs. The above-mentioned revenues and values are deflated using price indices obtained from EUROSTAT, using 2005 as the base year. The explanatory variables z_{it} affecting the inefficiency term, u_{it} , in equation (3) consist of a dummy variable (dummy ASP-payments), the value of agri-environmental subsidies (agri-environmental subsidies), the ratio of milk production per milk cow (intensity), the share of rented land in total utilized land (land share), the share of family labor in total labor (labor share) and the share of milk production in total production (milk share).

4. Results

The complete results of the estimation of the hyperbolic distance function are available upon request. Here we only discuss the hyperbolic efficiency scores and the results of the policy-related determinants of inefficiency. Table 2 reports the summary statistics of the hyperbolic efficiency scores.

Table 2. Summary statistics of the hyperbolic efficiency scores (HE).

	Obs.	Mean	Std. Dev.	Min.	Max.
HE	2105	0.86	0.09	0.37	0.99

The mean hyperbolic efficiency is 0.86 implying that farms can improve their technical efficiency by increasing their desirable outputs production by $1/0.86=1.16$, i.e. by 16% while, at the same time, improve their environmental efficiency by reducing their undesirable outputs production by $1-0.86=0.14$, i.e. by 14%.

The estimates of the coefficients in the inefficiency component are presented in Table 3. The coefficient of the dummy variable that controls for the introduction of ASP and decoupled payments has a negative effect on hyperbolic efficiency. ASP and decoupled payments are expected to improve the environmental performance of farms as they oblige farmers to respect application standards for N and P and maintain their land in good agricultural and environmental condition. On the contrary, such measures imply worse technical performance of farms because of lower motivation of farmers to work efficiently. The result indicates that the overall effect is negative which in turn implies that the expected negative impact of these measures on technical efficiency dominates their positive effect on environmental efficiency.

Table 3. Estimates of the coefficients in the inefficiency component.

Variables	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
trend	-0.0205	0.0041	-4.9800	0.0000	-0.0285	-0.0124
dummy ASP-payments	0.0474	0.0140	3.3900	0.0010	0.0200	0.0749
agri-environmental subsidies	0.0018	0.0015	1.1700	0.2400	-0.0012	0.0047
intensity	-0.0003	0.0000	-16.2500	0.0000	-0.0003	-0.0003
land share	-0.0002	0.0002	-0.7900	0.4270	-0.0005	0.0002
labor share	-0.0008	0.0003	-2.7300	0.0060	-0.0013	-0.0002
milk share	-0.0039	0.0017	-2.3300	0.0200	-0.0072	-0.0006
constant	1.2406	0.1525	8.1400	0.0000	0.9418	1.5394

A potential explanation of this result is the following: nutrients, and particularly P, can accumulate in the soil (Keyzer, 2010). Hence, a reduction of fertilizer use will not instantaneously reduce the production of nutrient surplus. On the other hand, fertilizers and output are related through the well-known production function (S shape). Our efficiency scores suggest that farms do not operate at their maximum efficiency level. Hence, they should operate somewhere below where the production function is steeper, thus implying a higher decrease in desirable outputs compared to the minor decline of undesirable outputs as a result of feed and fertilizer reduction.

Agri-environmental subsidies are statistically insignificant which may occur because their effect on technical and environmental efficiency offset each other. Intensity is positively related with hyperbolic efficiency. It is apparent that higher milk production implies better technical performance of farms. Concerning environmental efficiency, one could argue that higher milk production may be associated with more animal wastes per hectare and therefore lower environmental performance. However, according to Oenema et al. (2011) Dutch dairy farmers, as a result of environmental regulations, have adapted several nutrient management

practices such as restriction of grazing time, appropriate storage of manure etc. Hence, under appropriate management practices, intensification of milk production does not automatically imply worse environmental performance.

5. Concluding remarks

Using a hyperbolic distance function and the Battese and Coelli (1995) approach of inefficiency determinants we investigated the effects of agri-environmental policies and intensification on the hyperbolic efficiency of Dutch dairy farms. The introduction of ASP and decoupled payments decreased the hyperbolic efficiency of farms revealing a dominance of the expected negative impact of these policies on technical efficiency over their positive effect on environmental efficiency. This result illustrates the trade-off between technical and environmental efficiency and provides a warning that policies addressing environmental concerns need to be carefully designed in order to avoid that environmental efficiency gains are offset by the simultaneous losses in technical efficiency. We find no significant relationship between agri-environmental subsidies and hyperbolic efficiency. The insignificant relationship may arise because policies, intended to strengthen the environmental performance of farms, at the same time reduce their technical performance. Intensification appears to be positively associated with hyperbolic efficiency which is also evident in previous studies (Reinhard et al., 1999). Apart from the expected positive effect of intensification on technical efficiency, this result reveals that it should not be a panacea that intensification is associated with a decline in environmental efficiency, as appropriate nutrient management practices may simultaneously reduce detrimental impacts on the environment.

Disclaimer

The Data used in the present work stems from the Dutch FADN system as collected by the Dutch Agricultural Economics Research Institute (LEI). The Centre of Economic Information (CEI) has provided access to these data. Results shown are and remain entirely the responsibility of the author(s); neither they represent LEI / CEI views nor constitute official statistics.

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