https://doi.org/10.17221/137/2022-AGRICECON

Environmental strategy and firm performance: A new methodological proposal

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Citation: Arbelo-Pérez M., Armas-Cruz Y., Arbelo A. (2022): Environmental strategy and firm performance: A new methodological proposal. Agric. Econ. – Czech, 68: 283–292.

Abstract: Environmental strategies and their effects on firm performance are receiving increased attention in the literature, but the results are inconclusive. To fill this gap, we propose to evaluate the effect of environmental strategies on firm performance, thereby making two significant contributions. The first is the use of Bayesian techniques to estimate a stochastic frontier model with random coefficients to evaluate the relationship between environmental strategies and performance at the individual firm level, thus adequately incorporating heterogeneity; the second is the adoption of profit efficiency as a measure of firm performance. To test this idea, we studied the effect of a set of pollutants on profit efficiency in a sample of livestock firms in Spain. The results reveal that *i*) the success of environmental strategies depends on the properties and internal characteristics of each firm and the environment in which it operates and *ii*) the mean efficiency is 55.80%, which implies that these firms are losing on average 44.20% of their maximum potential profit. These results have significant strategic implications for firms' ability to achieve a competitive advantage.

Keywords: Bayesian approach; environmental strategies; heterogeneity; livestock industry; profit efficiency; resource based view

Society's growing interest in the environmental impact of business activity encourages management to formulate strategies that minimise the impact of business on the environment (Porter and Reinhardt 2007). In highly competitive environments, firms must embrace the challenge posed by environmental issues. To meet this challenge, firms seek to maximise the efficiency of their production processes while reducing their environmental impact. This means being respectful of the environment while at the same time generating business value. To achieve this goal, firms must efficiently manage the life cycle of products by improving the use of production inputs and reducing waste and pollution (Schmidheiny and Timberlake 1992), thus connecting environmental excellence with corporate excellence (DeSimone and Popoff 2000).

Despite the growing interest and the extensive literature that suggests that being environmentally responsible and generating business value are compatible (Hart and Ahuja 1996; Murty and Kumar 2003; Montabon et al. 2007; Burnett and Hansen 2008), many firms continue to be reluctant to intensify eco-friendly practices because there is no clear empirical evidence that the benefits of these practices are greater than the costs. In fact, there are studies that suggest that environmental protection has a negative impact on firm performance (Worrell et al. 1995; Cordeiro and Sarkis 1997).

One possible reason why these studies did not reach a conclusive result is that their main focuses are the effects on costs and the evaluation of technical or cost efficiencies. It is expected that greater investment in research and the use of clean technologies will reduce costs by reducing the resources used and modifying the resources selected for use (Porter and van der Linde 1995; Mohr 2002). In addition, a pollution is a form of economic inefficiency, and its reduction increases

https://doi.org/10.17221/137/2022-AGRICECON

production efficiency (Porter and van der Linde 1995; King and Lenox 2002).

However, eco-friendly practices can also increase production costs since, for example, pollution is a negative output, and the reduction of a negative output requires additional inputs and, therefore, an increase in costs. In addition, these practices are expensive in many cases, and their results are usually obtained in the long term. Therefore, there is a general belief that environmental protection erodes competitiveness (Porter and van der Linde 1995), and it is seen more as an obstacle than as an opportunity to achieve competitive advantages. These mixed results partly explain the divergent findings in the empirical literature on the impact of environmental strategies on firm performance.

Similarly, it should be considered that environmental management affects more than only a firm's costs. Firms that adopt eco-friendly practices can also be distinguished more easily in the market, which improves their image (Montabon et al. 2007) and increases the demand for their products and, as a result, establishes a premium for them (Sinkin et al. 2008). The number of environmentally conscious customers is increasing, and these customers are very likely to be willing to pay a premium for and demand products or services that are produced in an environmentally friendly manner. As a result, firms can earn more from the sale of their environmentally friendly products or services.

A second explanation for the divergent results in the empirical literature regarding the effect of environmental management on performance is the heterogeneity across firms, even within the same sector. To estimate efficiency, many empirical studies use methodologies that assume that all firms operate under the same production frontier and therefore assume that there is homogeneity across firms. However, the central idea of the resource-based view (RBV) of the firm (Wernerfelt 1984; Barney 1991) is that firms are heterogeneous in terms of the resources they have. For example, technological advances are not simultaneously disseminated to all firms (Reinganum 1989; Berger and Mester 2003). Therefore, it seems realistic to assume that firms have different production possibilities, and in that case, it is more appropriate to study the effect of environmental management on firm performance using random coefficients models in which firms are assumed to be heterogeneous.

In our opinion, the previous considerations show that the relationship between environmental strategy and firm performance requires a more in-depth study. At the macroeconomic level, the connection between environmental and economic efficiency is studied in terms of circular economy (CE) (Kirchherr et al. 2017). For example, Aden (2016) shows the compatibility between the reduction of greenhouse gases (GHG), such as CO_2, and economic growth for a sample of 21 countries. This connection is more relevant as countries embark on the transition to a new climate economy. The CE paradigm is being more and more explored by researchers and practitioners. However, literature shows a lack of research about the assessment phase of CE strategies at the micro level (Elia et al. 2017).

At the firm level, the empirical evidence has mainly focused on the evaluation of cost efficiencies and ignores the important effects that the implementation of green practices has on revenue and its interaction with the costs of the firm (profit efficiency). In other terms, there are no studies that address the effect of environmental strategies on firm profit efficiency. Furthermore, the empirical methodologies that are traditionally used do not adequately incorporate the internal characteristics and properties of firms.

The purpose of this paper is to help fill the gap in the literature by evaluating the effect of environmental strategies on profit efficiency, used as a measure of firm performance, through the estimation of a Bayesian stochastic frontier model with random coefficients. It is important for managers to know whether adopting these strategies in their operations is an opportunity to achieve competitive advantages for the firm. This paper makes at least two important contributions to the literature. First, there is no empirical evidence that has evaluated the effect of environmental strategies on profit efficiency as a measure of performance. Second, this effect is evaluated using a methodology that adequately incorporates heterogeneity across firms. Thus far, we are not aware of any study that estimates the relationship between environmental strategy and performance at the individual firm level.

MATERIAL AND METHODS

The classical models used to estimate efficiency assume that all firms face the same production frontier; that is, they share the same resources and capabilities. Thus, the only difference across firms is the efficiency in resource management. However, as indicated above, the basis of RBV is that resources and capabilities are not distributed homogeneously across firms and are not perfectly mobile (Barney 1991). It is therefore expected that, even within the same economic sector, firms with different resources and capabilities

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coexist. Thus, the assumption of the classical approach, which assumes homogeneity across firms, is unrealistic and can lead to biased efficiency estimates (Galán et al. 2014). Therefore, it is necessary to use methodologies that relax the assumption of homogeneity across firms (Kutlu et al. 2020).

Tsionas (2002) proposes a stochastic frontier model with random coefficients, such that each firm faces its own production frontier. The main objective of this model is to improve the accuracy of efficiency level estimations by separating the inefficiency of each firm (firm-specific efficiency) from the differences in the amount of resources across the firms in the sample. The model of Tsionas (2002) can be expressed as follows:

$$y_{it} = \alpha + x_{it}\beta_i + v_{it} \pm u_{it}, \quad i = 1, \ldots, N, \quad t = 1, \ldots, T \qquad (1)$$

where: y_{it} – dependent variable [earnings before interest and taxes (EBIT)]; α – intercept; x_{it} – independent variables (quantity of the outputs and price of the inputs); β_i – vector of random parameters that enables the differences across firms to be captured and establishes an optimal frontier for each firm; v_{it} – random error that follows a normal distribution and captures any measurement error or variables that are not under business control; u_{it} – inefficiency following a non-negative distribution.

In addition, to study the effect that different pollutants have on the efficiency of each firm, we extend the model of Tsionas (2002) to the inefficiency function. In this manner, we can determine the effect of each pollutant on the efficiency of each firm individually. This methodology provides managers with more information than traditional methods, which can only determine the average effect of each covariate on the efficiency of the firms in the sample. As stated by Mackey et al. (2017), the average effect (positive or negative) of a certain variable on firm performance, in general, is not necessarily the same as the average effect of that variable on a particular firm.

Assuming that it follows an exponential distribution of parameter λ_{it}, the inefficiency function with random coefficients is given by the following formula:

$$u_{it} \sim \exp\left(\lambda_{it}\right)$$
$$\lambda_{it} = \exp\left(\gamma_0 + \gamma_i z_{it}\right) \qquad (2)$$

where: λ_{it} – exponential distribution of parameter; γ_0 – intercept; γ_i – vector of specific parameters of each firm that captures the effect that each covariate has on the efficiency of each firm; z_{it} – vector of the covariates.

Once Equations (1, 2) have been defined, the next step is to determine the method for estimating them. At present, the most widely used method is the maximum likelihood method (Wanke et al. 2020), in which confidence intervals are estimated to test whether a parameter is equal to or different from zero. However, Bayesian inference is gaining increasing importance in the social sciences (Kruschke et al. 2012; Zyphur and Oswald 2015). Unlike the maximum likelihood method, Bayesian inference estimates the probability distribution of a parameter, which helps determine the probability that the parameter is greater or less than zero or any other given value. This is especially important in strategic management since any strategy is expected to influence firm performance, regardless of how small the effect is (Mackey et al. 2017).

Furthermore, the Bayesian approach allows prior information, and not just the data at hand, to be incorporated into the estimated parameters (Carvalho and Marques 2016); this allows more accurate data to be obtained (Kruschke et al. 2012; Zyphur and Oswald 2015). Bayesian inference also offers greater flexibility when estimating more complex models and incorporating different distributions (Kruschke et al. 2012; Zyphur and Oswald 2015; Assaf et al. 2017). Additionally, this method has fewer problems than the maximum likelihood method when the sample size is small (Griffin and Steel 2007; Kruschke et al. 2012; Zyphur and Oswald 2015). Therefore, this study uses the Bayesian methodology to estimate Equations (1, 2).

Once the estimation method has been chosen, to complete the assumptions of our model and following Tsionas (2002), we consider that parameters β_i follow a multivariate normal distribution with mean $\overline{\beta}$ and deviation Ω. At the same time, $\overline{\beta}$ and α follow a normal distribution, such that $\overline{\beta}, \alpha \sim N\left(0, 10^{-6}\right)$ and Ω is an inverted Wishart distribution. Additionally, $\exp(\gamma_i)$ follows an exponential distribution with parameter γ^*, and $\exp(\gamma_0)$ and γ^* follow an exponential distribution with parameter $-\ln(r^*)$. Parameter r^* represents the mean efficiency of the firms, and in our case, we consider that $r^* \sim \text{unif}\left(0.1, 0.9\right)$ given the lack of previous evidence in the sector. Finally, v_{it} follows a normal distribution with mean 0 and deviation σ_v^2, such that $\sigma_v^{-2} \sim G\left(0.001, 0.001\right)$.

The posterior distributions were generated using the Markov chain Monte Carlo (MCMC) procedure and the Gibbs algorithm with data augmentation (Koop

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et al. 1995). In total, 30 000 interactions were generated, of which the first 5 000 were discarded to avoid the sensitivity of the initial values. Finally, the implementation was carried out using WinBUGS 14 software.

RESULTS AND DISCUSSION

Results

Data and research model. The dataset for this study was obtained from the Iberian Balance Sheet Analysis System (SABI) database and from the State Pollutant Release and Transfer Register (PRTR) of the Ministry for the Ecological Transition and the Demographic Challenge of the Government of Spain. The data on polluting waste from firms in Category 7 – Livestock and intensive aquaculture was obtained from the PRTR (2020). This category was chosen since livestock production, mainly its intensive and extensive resource exploitation systems, has a significant impact on the environment, affecting air, soil and water. Livestock accounts for nearly 18% of global GHG emissions, which is higher than the contribution of the transport sector (Steinfeld et al. 2006). The accounting and financial data of these firms were also extracted from the SABI database (2020). Firms that did not have all the necessary data for this research available throughout the study period (2013–2018) were excluded. Finally, the sample consisted of balanced data from 502 firms, which covers a total of 3 012 observations (502 firms × 6 years). The frequency of the data is annual.

Since there was no direct information on the price of inputs, these were approximated using the following proxy variables: w_1 – price of labour (ratio of personnel expenses to the number of employees); w_2 – price of materials (ratio of material costs to operating revenue); w_3 – price of other operating expenses (ratio of other operating expenses to operating revenue); and w_4 – price of capital (ratio of depreciation to total fixed assets). Additionally, we considered the following output variables: x_1 – net sales amount and x_2 – other operating revenue. The dependent variable of the profit function is earnings before interest and taxes (EBIT) (π).

The following most common waste products produced by the livestock industry were defined as variables of the inefficiency function [Equation (2)]: Z_1 – methane (CH_4); Z_2 – ammonia (NH_3); Z_3 – non-hazardous waste (NHW); and Z_4 – hazardous waste (HW). The two gases were chosen because they are the gases with the greatest emission in livestock production [livestock production is responsible for 37% of methane (CH_4) and 68% of ammonia (NH_3) emissions worldwide] (Steinfeld et al. 2006). HWs are those substances listed in the PRTR of the Ministry of Environment of the Government of Spain, in which waste recovery and disposal operations are recorded, and those in the European list of wastes, which adopts as a reference the European Union Directive 2008/98/EC on waste.

Table 1 provides descriptive data for the variables in the model. The monetary variables were deflated using the general consumer price index, calculated as 2016 = 100.

To evaluate the profit efficiency of the sample firms, we used the alternative profit function to specify the frontier established in Equation (1). The functional form chosen was the translog form (Christensen et al. 1973), which is the most commonly used form in this type of research. However, the translog profit function has a disadvantage when the natural logarithm is applied to the EBIT. This variable can take negative values, and the natural logarithm of a negative number is undefined. To solve this problem, we followed Bos and Koetter (2011), who proposed the creation of a new independent variable called the negative profit indicator (*NPI*). This variable takes a value of zero when the EBIT is positive, and when the EBIT is negative, it takes the absolute value of the EBIT. Similarly, the dependent variable takes a value of zero when the EBIT is negative and the corresponding value when the EBIT is positive. This mechanism 'enhances rank stability and discriminatory power and improves the precision of profit efficiency scores' (Bos and Koetter 2011, p. 307) in comparison with the classic truncation or rescaling methods. Thus, the estimated profit function can be expressed as follows:

$$\ln\left(\frac{\pi_{it}}{w_{4,it}}\right) = \alpha + \sum_{j=1}^{2}\beta_{j,i}\ln x_{j,it} + \sum_{s=1}^{3}\delta_{s,i}\ln\left(\frac{w_{s,it}}{w_{4,it}}\right) + \frac{1}{2}\sum_{j=1}^{2}\sum_{k=1}^{2}\beta_{jk,i}\ln x_{j,it}\ln x_{k,it} + \frac{1}{2}\sum_{s=1}^{3}\sum_{r=1}^{3}\delta_{sr,i}\ln\left(\frac{w_{s,it}}{w_{4,it}}\right)\ln\left(\frac{w_{r,it}}{w_{4,it}}\right) + \sum_{j=1}^{2}\sum_{s=1}^{3}\rho_{js,i}\ln x_{j,it}\ln\left(\frac{w_{s,it}}{w_{4,it}}\right) + \theta_i \ln NPI_{it} + v_{it} - u_{it} \quad (3)$$

$i = 1, \dots, N$ firms; $t = 1, \dots, T$ years

where: π_{it} – earnings before interest and taxes (EBIT) of firm i in the year t; x_j, x_k – outputs; w_s, w_r – inputs;

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β_i, δ_i, ρ_i, θ_i – parameters representing the random coefficients to be estimated; w_4 – price of capital (ratio of depreciation to total fixed assets); NPI_{it} – negative profit indicator.

Note that in the case of Equation (3), the term u_{it} is introduced with a negative sign since the higher the inefficiency value is, the lower the profit will be. Linear homogeneity is achieved by normalising EBIT and input prices by the price of capital (w_4). Symmetry is achieved by imposing $\beta_{jk,\,i} = \beta_{kj,\,i}$ and $\delta_{sr,\,i} = \delta_{rs,\,i}$.

The inefficiency function [Equation (2)] is estimated in conjunction with the profit frontier and is represented as follows:

$$u_{it} \sim \exp(\lambda_{it})$$
$$\lambda_{it} = \exp\left(\gamma_0 + \sum_{h=1}^{4} \gamma_{h,i} Z_{h,it}\right) \quad (4)$$

where: γ_i – random parameters to be estimated; Z – previously defined efficiency determinants.

Empirical findings. The existence of heterogeneity across firms requires focusing on the results at the firm level more than on the average effects in the sample. Therefore, the methodology used must consider the differences across individual firms and not be based on averages, which statistically neutralise such differences. To examine the relationship between environmental strategies and firm performance, this study uses the Bayesian methodology to estimate the stochastic frontier model with random coefficients described above. This methodology enables us to estimate the aforementioned relationship between environmental strategies and firm performance for each of the 502 firms in the sample. Since the number of estimated coefficients is very large, it is practically impossible to report them here. However, the Bayesian model used in this study also provides information on the average effects in the sample. Table 2 presents the posterior mean, standard deviation and 97.5% confidence interval of the mean parameters of Equation (3). It should be noted that although the coefficients estimated by the firm are not reported, these coefficients vary across firms, which indicates there is heterogeneity across the firms in the sample. Table 3 shows the mean effects of the inefficiency [Equation (4)]. Table 4 shows the efficiencies obtained across the study period (2013–2018). The random coefficients model considers that firms may have different amounts of resources and that, therefore, each firm will have its own efficient frontier. In this case, efficiency is measured by the distance from each firm's performance to its efficient frontier. The mean efficiency of the profit frontier with random coefficients is 55.80%, which implies that these firms are losing on average 44.20% of their maximum

Table 1. Descriptive statistics for the period between 2014 and 2018

Variable	Symbol	Unit	Minimum	Maximum	Mean	SD
EBIT	π	thousands of EUR	–4 563.9850	53 103.5309	437.9294	2 135.2799
Net sales amount	x_1	thousands of EUR	26.6315	305 594.2691	7 018.9389	21 830.6813
Other operating revenue	x_2	thousands of EUR	0.0000	2 785.4520	61.6101	178.5730
Price of labour	w_1	thousands of EUR	5.7672	48.8377	24.9771	7.0008
Price of materials	w_2	–	0.00004	0.98703	0.48390	0.31487
Price of other operating revenue	w_3	–	0.01249	0.67736	0.18713	0.12736
Price of capital	w_4	–	0.00050	0.40859	0.09203	0.06589
Methane (CH_4)	Z_1	kg	0.00	2 450 697.38	47 529.29	114 607.87
Ammonia (NH_3)	Z_2	kg	0.00	1 089 058.54	36 728.78	62 462.93
NHW	Z_3	kg	0	172 245 606	1 195 841	8 694 030
HW	Z_4	kg	0.00	35 852.20	226.71	1 392.50

EBIT – earnings before interest and taxes; NHW – non-hazardous waste; HW – hazardous waste
Source: Authors' own elaboration

https://doi.org/10.17221/137/2022-AGRICECON

Table 2. Posterior estimates of the profit frontier parameter distributions

Parameter	Mean	SD	97.5% confidence interval
α	11.9400	1.08000	[10.87, 15.32]
$\bar{\beta}_1$	−0.2766	0.07625	[−0.419, −0.1519]
$\bar{\beta}_2$	−0.0599	0.04904	[−0.1483, 0.03019]
$\bar{\delta}_1$	−2.0750	0.19790	[−2.435, −1.719]
$\bar{\delta}_2$	0.2888	0.01898	[0.2531, 0.3275]
$\bar{\delta}_3$	−0.4121	0.10410	[−0.5355, −0.1788]
$\bar{\beta}_{11}$	−0.0696	0.05077	[−0.155, 0.02538]
$\bar{\beta}_{12}$	0.4269	0.04369	[0.3512, 0.5107]
$\bar{\beta}_{22}$	0.3673	0.07967	[0.2179, 0.4908]
$\bar{\delta}_{11}$	0.1581	0.04986	[0.05673, 0.2357]
$\bar{\delta}_{12}$	0.1660	0.02619	[0.1231, 0.2156]
$\bar{\delta}_{13}$	−0.4371	0.08953	[−0.5894, −0.259]
$\bar{\delta}_{22}$	0.2533	0.02485	[0.2158, 0.3058]
$\bar{\delta}_{23}$	−0.2013	0.06369	[−0.3074, −0.08061]
$\bar{\delta}_{33}$	−0.8028	0.08730	[−0.9686, −0.6412]
$\bar{\rho}_{11}$	0.2804	0.06298	[0.193, 0.4035]
$\bar{\rho}_{12}$	0.0150	0.04291	[−0.05958, 0.09536]
$\bar{\rho}_{13}$	0.4943	0.05700	[0.3775, 0.5881]
$\bar{\rho}_{21}$	−0.4985	0.04641	[−0.5887, −0.4202]
$\bar{\rho}_{22}$	0.0668	0.04764	[−0.02769, 0.1564]
$\bar{\rho}_{23}$	0.0234	0.05883	[−0.07744, 0.1334]
$\bar{\theta}$	−0.8095	0.04478	[−0.8676, −0.695]

Source: Authors' own elaboration

potential profit. The mean efficiency remains practically unchanged during the study period.

The central hypothesis of this study is that firms choose the environmental strategies that maximise performance (profit efficiency). Consequently, the study predicts that the effect of these strategies on profit efficiency will depend on the resources and capabilities of each firm and the environment in which it operates. Therefore, the empirical implementation of this hypothesis requires assessing the probable effect of the environmental strategies on profit efficiency. Table 5 shows the probability that a reduction in pollutants will have a positive effect on profit efficiency; a probability of less than 0.5 indicates a greater likelihood that the effect will be negative. For example, the probability that a reduction in methane will have a positive effect on profit efficiency is 24.70%. Therefore, there is a 75.30% probability that a reduction in methane will have a negative effect. Likewise, it should be noted that the probabilities indicated in Table 5 do not represent the effect size.

Table 3. Inefficiency function

Parameter	Variable	Mean	SD	CV
γ_0	constant	0.3250	0.4002	–
γ_1	Z_1	0.2275	0.9074	3.9880
γ_2	Z_2	−0.4050	0.9133	2.2551
γ_3	Z_3	−0.1314	0.3191	2.4291
γ_4	Z_4	−0.3824	0.1963	0.5134

Z_1 – methane (CH_4); Z_2 – ammonia (NH_3); Z_3 – non-hazardous waste (NHW); Z_4 – hazardous waste (HW); CV – coefficient of variation

Source: Authors' own elaboration

Table 4. Mean profit efficiency (%)

Year	Profit efficiency
2013	54.42
2014	55.95
2015	54.06
2016	55.33
2017	59.43
2018	55.64
Mean	55.80

Source: Authors' own elaboration

Consequently, the specific characteristics of each pollutant, the environmental management approach adopted by the firm, its initial level of environmental performance and the marginal cost/benefit ratio of the reduction of emissions could explain why for some firms, reductions in the analysed pollutants have a positive impact on profit efficiency, while for others, the impact is negative. For example, methane accounts for the highest volume of emissions in the livestock sector and, consequently, the level of environmental performance required from livestock firms to address the emission of this gas is high, which reduces the marginal profit derived from methane reduction. In addition, methane emissions suggest energy inefficiency in the animal and

Table 5. Probability that a reduction in pollutants will have a positive effect on profit efficiency

Variable	Profit efficiency
Z_1	0.2470
Z_2	0.5876
Z_3	0.8566
Z_4	0.9841

Z_1 – methane (CH_4); Z_2 – ammonia (NH_3); Z_3 – non-hazardous waste (NHW); Z_4 – hazardous waste (HW)

Source: Authors' own elaboration

https://doi.org/10.17221/137/2022-AGRICECON

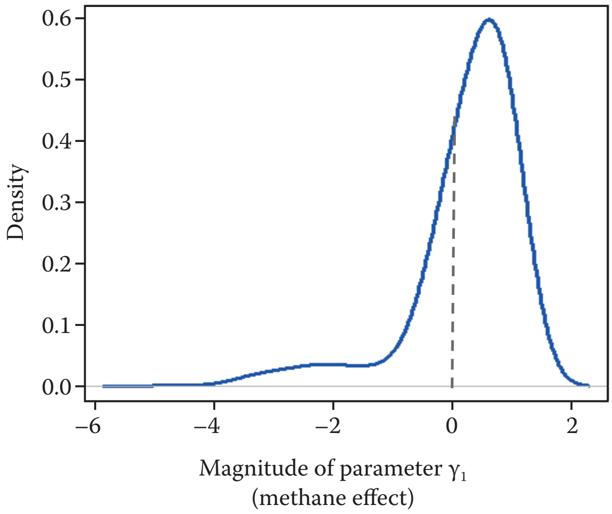

Figure 1. Effect of methane (CH_4) on profit efficiency

Source: Authors' own elaboration

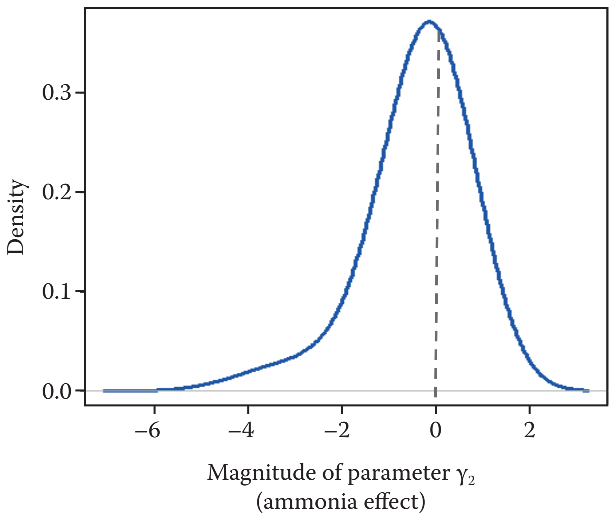

Figure 2. Effect of ammonia (NH_3) on profit efficiency

Source: Authors' own elaboration

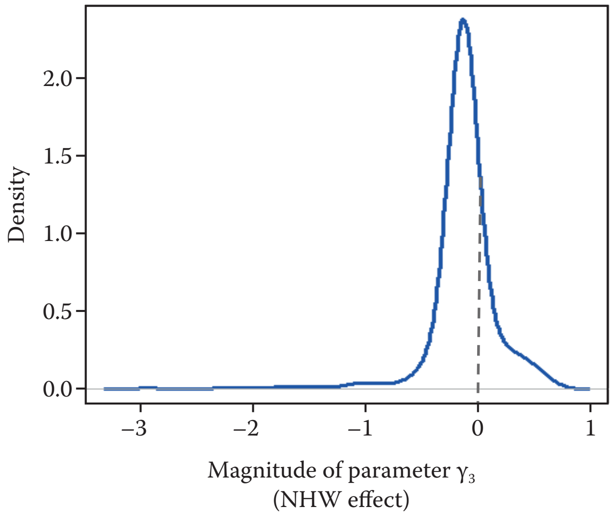

Figure 3. Effect of non-hazardous waste (NHW) on profit efficiency

Source: Authors' own elaboration

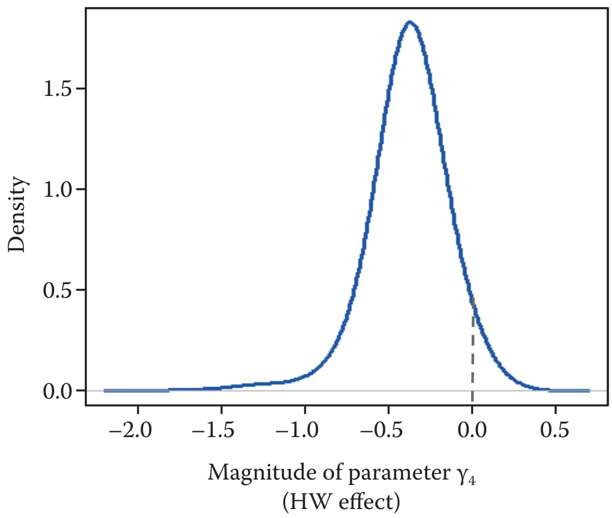

Figure 4. Effect of hazardous waste (HW) on profit efficiency

Source: Authors' own elaboration

are reduced through nutritional manipulation and supplementation, including the use of high-quality forage and grains, which increase costs compared to conventional feeding (Cárdenas and Flores 2012).

Although a single metric of the estimated probability can be useful, the graphical representation of the posterior distributions provides more information. Figures 1–4 show the probability distribution of the inefficiency function parameters. Note that in the case of HW, the top of the curve is centred on –0.4, which indicates that the most probable effect of HW generation is a decrease in profit efficiency by 40%. It should also be noted that the area to the left of zero shows the probability that the effect of releasing gases or waste on profit efficiency will be negative. On the contrary, the area to the right of zero shows the probability that the effect will be positive.

Discussion

The purpose of this paper was to introduce a new framework for evaluating the relationship between environmental strategies and firm performance. The results reveal that the effect of reducing gases or waste

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on profit efficiency differs significantly across firms not only in terms of intensity but also in terms of direction. A positive effect indicates the probability that the firm will achieve higher profit efficiency and, therefore, higher performance. These results confirm the marked heterogeneity across the firms in the sample and the need to make separate predictions for each firm. As hypothesised, firms choose the environmental strategies that maximise their performance, depending on their resources and the distinctive capabilities that enable them to use those resources efficiently. These results are consistent with the RBV postulates.

In the case of HW, the reduction of these pollutants positively impacts profit efficiency for nearly 100% of the analysed firms. However, for the other pollutants studied, the effects of reduction on profit efficiency differ across firms in both intensity and direction. Consistent with the fundamental premise of the RBV, the reason underlying this result is the specific heterogeneous aspects of the firms in terms of their resources and capacities, which condition the greater or lesser success of the same environmental strategy. This firm heterogeneity is manifested in a series of determinants that influence the implementation of different strategic formulas for environmental management and result in different levels of environmental performance and efficiency.

Among the determinants that the RBV identifies as the explanation for differences in competitive positioning, intangible factors (skills) stand out; these include know-how, accumulated experience, management attitude, training and motivation, policies and concurrent strategies, among other factors. These distinctive resources and capabilities, when incorporated into the environmental strategy of the firm, are reflected in the cost structure of the firm, its potential market impact or both.

Returns on corporate environmental management also depend on how the firm's environmental strategy evolves according to the dynamism of its resources and capabilities. To comply with regulations, firms need to incorporate an end-of-the-pipe approach to pollution abatement before they cultivate the knowledge, experience and capacity to apply a cleaner production approach, which could significantly increase environmental and economic performance (Fujii et al. 2013). Additionally, the marginal abatement cost of pollution is higher than the marginal benefit of pollution abatement when a firm's environmental performance is high because, in that initial phase, there are more options in terms of effective technologies for the reduction of costs (Fujii et al. 2013). Therefore, the specific characteristics of each pollutant, the environmental management approach adopted by the firm, its initial level of environmental performance and the marginal cost/benefit ratio of the reduction of emissions could explain why for some firms, reductions in the analysed pollutants have a positive impact on profit efficiency, while for others, the impact is negative.

Because our interest is in studying the relationship between environmental strategy and performance at the individual firm level and not for a hypothetical average firm, our results are not directly comparable with those of the literature on other sectors. However, they could help explain the contradictory results of previous studies. For example, in a study on manufacturing firms in the United Kingdom, Ramanathan (2018) concludes that there is a positive curvilinear relationship between environmental performance and firm performance. Burnett and Hansen (2008) also found a positive relationship between environmental performance and firm performance in a study on the electric utility industry in the USA. In contrast, in a study on the supermarket industry in the United Kingdom, Moore (2001) concludes that there is a negative relationship between environmental performance and firm performance. Other authors conclude that there is no direct relationship between environmental performance and firm performance in pulp manufacturing mills (Thornton et al. 2003).

CONCLUSION

This paper presents two key contributions to the literature on environmental strategy. First, we use Bayesian techniques to estimate a stochastic frontier model with random coefficients to examine the relationship between environmental strategies and firm performance. This methodology incorporates the heterogeneity across firms and estimates this relationship at an individual firm level. The ability to make predictions for each firm is one of the main advantages of the Bayesian models. Second, we use profit efficiency as a performance measure since it reflects the revenue generated from a competitive advantage better than traditional financial measures do. This performance measure is more consistent with the competitive advantage concept expressed by Peteraf and Barney (2003, p. 313) who point out that a 'competitive advantage is expressed in terms of the ability to create relatively more economic value' and that, clearly, 'greater value implies greater efficiency'.

The results enable one to conclude that the effect of a firm's environmental strategy on its performance depends on its internal characteristics and properties

https://doi.org/10.17221/137/2022-AGRICECON

and on the environment in which the firm operates. Consequently, for some firms, a reduction in the emission of gases or waste has a positive effect on their performance, while for other firms the reduction can have a negative effect. Thus, the effect of the environmental strategy on performance is unevenly distributed across firms.

This conclusion could partly explain the inconclusive results of previous empirical studies on the effects of environmental strategies on firm performance. When the average effect is estimated instead of the effect for each individual firm, the differences between firms are ignored, and the results show only the average effect of the firms in the sample. The average effect may be positive (or negative) depending on the type and characteristics of the sample of firms used. This average effect says nothing about the effect for each individual firm, which can differ in both sign and intensity.

These results have important repercussions on strategic management. If heterogeneity between firms is not considered, the efforts to identify the relationship between environmental strategies and performance can lead to incorrect results. If the average relationship found between a reduction in gases and/or waste and efficiency is, for example, positive, managers could interpret this result to mean that any firm that formulates strategies that respect the environment improves its performance. In reality, a positive (or negative) mean coefficient represents the average relationship for all the firms in the sample. However, it is possible that for various firms the sign of this relationship is different from that suggested by the mean coefficient. Knowing the specific effect for each firm provides managers greater predictive capacity in the formulation of their environmental strategies, not only because of the positive or negative sign of the effect but also because of its intensity.

This study has some limitations, which must be considered when interpreting its results. The first limitation stems from the database used. The available data do not facilitate the direct estimation of certain variables of the model, such as the price of the inputs. Second, the intertemporal effect between environmental strategies and firm performance is not examined. It seems evident that the direction of the effect of environmental strategies on firm performance is different in the short term than in the long term. Third, the environmental performance measure used does not include all the dimensions of contamination. Clearly, only considering certain contaminants while ignoring others can be problematic. However, we believe that these limitations do not invalidate the results.

Finally, future research could validate these results in other industries and in other geographical environments. Similarly, they could extend the model to incorporate the intertemporal effect and thus observe how the direction of the environment-performance relationship varies over time.

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Received: May 10, 2022
Accepted: August 1, 2022
Published online: August 22, 2022