Received 21 November 2018
Revised 17 February 2019
Accepted 18 February 2019

Evaluating the effect of subsidies for rural development on agri-food and forestry firms

Technical progress and efficiency

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Abstract

Purpose – This paper aims to evaluate the impact of the subsidies established by Measure 123 of the Rural Development Policy on the productivity of a sample of agri-food and forestry companies in the region of Asturias over the period 2006-2009.

Design/methodology/approach – The authors estimate a stochastic frontier function which allows subsidies to be considered as affecting both the level of technical efficiency and technical progress.

Findings – The results show that while subsidies have a positive effect on the technical progress of companies in the agri-food industry, for the forestry industry, the effect materializes as an improvement in technical efficiency. Additionally, other factors affecting either, technical progress and technical efficiency were identified.

Originality/value – This study adopts a model that allows the separate identification of the effect of subsidies on the level of efficiency, on the one hand, and on the technical progress, on the other.

Keywords Rural development, Subsidies, Efficiency, Productivity

Paper type Research paper

1. Introduction

Predominantly rural areas in the European Union (EU) represent 52 per cent of the territory and 23 per cent of the population. Per capita income in these areas is relatively low compared to that of urban areas due to a less developed service sector together with

JEL classification – D24, H25, M21

The authors thank the Department of the Rural Environment and Fisheries of the Regional Government of the Principality of Asturias and the firms analyzed for providing the data.

Applied Economic Analysis
Vol. 27 No. 80, 2019
pp. 150-167
Emerald Publishing Limited
2632-7627
DOI 10.1108/AEA-06-2019-0004

a low level of infrastructure stock (European Commission, 2013a). In this context, the EU's Rural Development Policy focuses on reducing income inequalities between urban and rural residents. In particular, Article 28 of Council Regulation (EC) n° 1698/2005 establishes the support schemes for investments to improve the agri-food and forestry sectors' economic performance in rural areas through the introduction of new products, processes and technologies, as well as improving product transformation and commercialization. These support schemes are articulated via the so-called Measure 123.

Existing literature on this topic indicates that it is merely an empirical question whether these support schemes positively influence the productivity of agri-food and forestry firms or not. To shed more light on the matter, this paper analyzes the effect of the subsidies introduced under Measure 123 on the productivity of agri-food and forestry firms in Asturias (Spain), where most of its 78 municipalities are considered rural. We estimate a stochastic frontier function that allows us to examine the effect of subsidies on both technical efficiency and technical progress. Moreover, we analyze the effect of a set of managerial variables (such as online commerce, quality certificates, organic production and other variables) on firms' productivity. It is important to note that, while this methodology has been widely used to analyze the effect of subsidies on agricultural productivity (Kumbhakar and Lien, 2010; Zhu and Oude Lansink, 2010; Bojneca and Latruffe, 2013), it is not commonly used to assess the impact of subsidies in the case of industrial firms.

To analyze this issue, we use data on agri-food and forestry firms from Asturias (Spain), all recipients of subsidies through the Measure 123 for the period 2006-2009. It should be noted that the construction of the database was made possible thanks to an agreement with the Department of Rural Environment and Fisheries of the Principality of Asturias. This allowed us to obtain information on the subsidies granted through the aforementioned Measure 123.

The remainder of the paper is organized as follows. Section 2 discusses the relevant literature on subsidies and their impact on productivity. Section 3 introduces the econometric model that we estimate in the empirical application. The data used in the analysis is described in Section 4. In Sections 5 and 6, we discuss the main results and the return on subsidies, respectively. Section 7 concludes.

2. The effect of subsidies on firms' productivity

There is no consensus in the literature on the effect of public subsidies on firms' performance (Bergström, 2000; Calvo-Flores Segura *et al.*, 2004). On the one hand, market failures may hamper firms' competitiveness, with subsidies on investments acting as a tool to promote modernization and economic growth in the long run. On the other hand, "government failures" may arise if regulators have an incentive to pursue policies focused on their political rather than economic returns, which may lead to a suboptimal resource allocation. Moreover, the implementation of subsidies may generate allocative inefficiencies for recipient firms as these are incentivized to change their capital/labor mix. Lastly, subsidies generate a safe cushion for recipient firms that may reduce the incentives to improve management practices.

Despite the controversy about the implementation of subsidies for promoting investment, these have been widely used in most of the developed world, including European countries (Tzelepis and Skuras, 2006). In this context, there exists some consensus regarding the need to provide rationality to the implementation of this type of support

schemes, which should be defined in a strategic plan evaluated through an analysis of the effect on recipient firms (Friedman, 1994).

The ambiguity in the effect of subsidies has caused empirical analysis to focus on their impact on economic activity. In this sense, studies analyzing the impact on recipient firms of subsidies designed for investment purposes usually consider multiple objectives and methodologies, obtaining mixed results that prevent the generalization of conclusions with respect to their influence on economic activity.

Bernini and Pellegrini (2011) analyze the effect of subsidies for capital projects on the evolution of production, labor and capital assets. They indicate that the increase in these variables was higher for recipient firms. Moreover, they also reveal that the increase in total factor productivity and labor productivity is lower for recipient firms, which may in turn jeopardize competitiveness in the long-run. Ankarhem *et al.* (2010) study the effect of regional subsidies for investment projects on firms' outcomes in terms of returns on equity and employment, finding that recipient firms do not show better rates of return than non-beneficiaries, and likewise, do not hire more employees. In Greece, Tzelepis and Skuras (2004) conclude that capital grants affect the growth of companies, but not other indicators related to their efficiency, profitability and financial structure. Harris and Trainor (2007) indicate that the perception of this type of support scheme reduces the likelihood of company closures in Northern Ireland. Van Tongeren (1998) finds that subsidies for investment projects are not sufficient for the purpose of changing investment decisions in Dutch industrial firms. Tzelepis and Skuras (2006) analyze the effect of support schemes on the strategic results of firms, concluding that, based on data from the Greek food and beverage sector, subsidies for capital investments contribute positively to the strategic orientation of firms through growth in sales and market power.

The impact of subsidies on total factor productivity has also been analyzed with different methodologies and results. Harris and Trainor (2005) conclude that regional subsidies for investment projects granted to companies in Northern Ireland improved total factor productivity. However, other studies (Bergström, 2000; OECD, 2001) show a negative correlation between subsidies for capital investments and productivity growth. Lee (1996) investigated the impacts of the government's industrial policy on the productivity growth of the Korean manufacturing sector. The study concludes that the level of subsidy perceived was not correlated with the total factor productivity in the beneficiary sectors. Harris and Robinson (2004) estimate a production function including dummy variables that identify whether firms have received subsidies for capital investment and observe that the impact of these aids on productivity is positive only in certain regions of Great Britain. Skuras *et al.* (2006) estimate production technology through a stochastic frontier function where the variables related to the perception of subsidies are included as additional inputs. The authors observe that the subsidy contributes positively to total factor productivity.

In terms of the effect of subsidies on firms' technical efficiency, Martin and Page (1983) develop a theoretical model in which they consider subsidies as influencing managerial effort which, consequently, affects a firm's technical efficiency. The conclusions derived from the model suggest that the effect of subsidies on efficiency is ambiguous. Empirical studies also show conflicting results. Martin and Page (1983) find a negative effect of subsidies on the technical efficiency of forestry firms in Ghana. Piesse and Thirtle (2000) analyze data on agricultural and industrial firms in Hungary and conclude that subsidies are negatively correlated with efficiency at the beginning of the period analyzed and positively correlated at the end of it. Rezitis *et al.* (2003) find that subsidy programs for investment projects have not led to improvements in the efficiency of Greek agricultural

producers. De Jorge and Suárez (2011) find a negative correlation between the subsidies in R and D and the efficiency of Spanish manufacturing firms.

Finally, it should be noted that McCloud and Kumbhakar (2008) postulate that the impact of subsidies can affect both the level of technical efficiency and the technical progress in the technology applied to produce goods. Consequently, following their proposal, this study adopts a model that allows the separate identification of the effect of subsidies on the level of efficiency, on the one hand, and on the technical progress, on the other.

3. Model

To evaluate the effect of subsidies granted through the Measure 123, we estimate a stochastic frontier function. In its general form, this function is defined as:

$$\ln y_{it} = f(\ln x_{it}, ts_{it}, t;\ \beta) + v_{it} - u_{it} \tag{1}$$

where y_{it} is the output level for firm i in period t; x_{it} is a vector of inputs used by the firm; ts_{it} is a vector of variables affecting the technology used by the firm; β is a vector of parameters to be estimated; v_{it} is a random error and, last, u_{it} is an error term that takes positive values. In this sense, the frontier function, $f(x_{it}, ts_{It},\ t;\ \beta)$, that identifies the maximum output level that can be obtained for a particular level of input. This maximum level of output depends on the state of knowledge that generally evolves over time. To control for this, it is standard to include either a trend or temporal dummy variables that capture changes in technical progress during the period of analysis through shifts in the production frontier.

It should be noted that this procedure includes, in addition to technical progress, any other circumstance that positively or negatively affects the firms' production processes in different periods, so that the impact of time does not necessarily imply an increase in the level of output, conditional on the explanatory variables. The term v_{it} includes the influence of purely random effects on the firms' production. Finally, u_{it} reflects the degree to which the firm is able to exploit the production capacity offered by the technology. The distribution of this term may depend on certain variables that, consequently, influence the firms' level of efficiency. A null value of this term implies that the firm operates efficiently, while positive values imply that the produced output is less than the potential, evidencing the presence of technical inefficiency in production. The firms' level of efficiency can be determined as the ratio of the observed output to the one that would be obtained if the firm were technically efficient:

$$TE_{it} = \frac{\exp(f(\ln x_{it}, t;\ \beta) + v_{it} - u_{it})}{\exp(f(\ln x_{it}, t;\ \beta) + v_{it})} = \exp(-u_{it}) \tag{2}$$

The study of the impact of subsidies on firms' production functions has mainly been carried out in the literature under two alternative hypotheses. On the one hand, some studies include subsidies as a traditional input to directly capture their impact on the firms' output (Guan and Oude Lansink, 2006; Skuras *et al.*, 2006), which implies including subsidies in the x_{it} vector. However, this option presents certain problems, as inputs are necessary for production, but subsidies are not. That is, it is possible to produce without having received any subsidy, so the inclusion of subsidies in the input vector could prove problematic. On the other hand, some studies include subsidies as efficiency determinants (Piesse and Thirtle, 2000; De Jorge and Suárez, 2011).

However, as indicated above, McCloud and Kumbhakar (2008) argue that the perception of subsidies may allow the development of new production processes that result in an

impact on the potential offered by technology to transform inputs into outputs. Kumbhakar and Lien (2010) follow this approach and include the subsidies in the stochastic frontier model through a double track. On the one hand, they can be included as an efficiency determinant and, on the other hand, as a variable that influences the firms' technical progress. As previously mentioned, the subsidies associated with Measure 123 are aimed at the development of new products and processes as well as the improvement in the transformation and commercialization of products. Therefore, we consider that this type of subsidy would, in fact, be related both to technical progress (in the part related to the development of new products and processes) and to the technical efficiency of the companies (in the part related to the improvements in the transformation and commercialization).

Therefore, assuming that the technology frontier follows a translogarithmic functional form, the equation that defines the production frontier is the following:

$$\ln y_{it} = \beta_0 + \sum_{l=1}^{15} \beta_l D_l + \sum_{j=1}^{3} \beta_j \ln x_{jit} + \frac{1}{2}\sum_{j=1}^{3}\sum_{k=1}^{3} \beta_{jk} \ln x_{jit} \ln x_{kit} + \sum_{r=1}^{5} \beta_r ts_r + \sum_{t=2007}^{2009} \beta_t D_t + \beta_{Agrs} D_{Agr} s_{it} + \beta_{Fors} D_{For} s_{it} + v_{it} - u_{it} \quad (3)$$

where the condition of symmetry $\beta_{jk} = \beta_{kj}$ is imposed. The model assumes that firms' output is produced using three inputs: work (x_{1it}), capital (x_{2it}) and materials (x_{3it}). To capture differences in the technology associated with the different productive activities carried out by firms, the independent term is allowed to differentiate the activity of the company according to the classification NACE (Statistical nomenclature of economic activities of the European Community). Therefore, the parameter β_0 represents the independent term related with the NACE 147 activity, while the rest of the parameters capture the differences of the independent terms taking β_0 as reference.

The vector of variables ts includes a set of variables associated with differences in the technology used by the different firms. Thus, we include two variables related to the geographical situation of the company: Central and Coast. The first one indicates whether the company is located in one of the central municipalities of Asturias where about 80 per cent of the population resides. Firms located in the central part of Asturias have certain advantages and disadvantages. On the one hand, firms in this area have a greater proximity to the centers of consumption and better road infrastructure. On the other hand, these firms have a greater distance to the production centers of the materials used in agri-food and forestry production. Therefore, the effect of this dummy variable on the firms' is uncertain *a priori*. The second variable, Coast is included because the coastal zones enjoy a milder climate and, generally, maintain a less rugged orography. These factors would affect both the production and access to materials for further processing. It also includes two other dummy variables related to the production processes used by firms: Quality Certification and Electronic Commerce. The first one indicates whether the company has any quality certification related to ISO standards or not. Quality certification requires certain conditions that imply a certain degree of systematization and traceability to guide the production processes that the firm must use. Regarding the other variable, the realization of electronic commerce through the internet implies the use of marketing resources as well as facilitating immediate access to a large number of customers. Finally, we consider the organic variable that includes the proportion of sales revenue generated by organic production. This variable is included as a technology shifter as the certificate of organic production also requires the

realization of certain practices and their traceability, which influences the production processes of the firm. Moreover, organic production leads to the generation of products offering greater value added.

Shifts of the production frontier over time, usually associated with technical progress, are controlled through a set of temporary dummy variables (D_t). As mentioned above, we consider that subsidies (s_{it}) affect technical progress, contributing to a shift of the production frontier over time. However, this effect may be different between agri-food and forestry firms. To control for these differences, we interact the variable s_{it} with the D_{Agr} and D_{For} dummies, which refer to the agri-food and forestry sectors, respectively. We consider the normal/semi normal model proposed by Caudill *et al.* (1995). It assumes that the random term (v_{it}) follows a normal distribution with 0 mean and standard deviation σ_v, while the efficiency term (u_{it}) follows a semi normal distribution. Moreover, as seen in equation (4), the latter term is allowed to be heteroscedastic:

$$\ln\sigma_u = \alpha_0 + \alpha_{For}D_{For} + \sum_{h=1}^{3}\alpha_h z_{hit} + \alpha_{Agrs}D_{Agr}s_{it} + \alpha_{Fors}D_{For}s_{it} \quad (4)$$

We consider that this variance can take different values for agri-food and forestry firms. This is taken into consideration by including a dummy variable for forestry companies. The vector of z variables includes the staff's average age (Age staff), the proportion of output sold outside of Asturias (Sales outside) and the proportion of output that has a certificate of Protected Designation of Origin or Protected Geographical Indication (PDO/PGI). The staff's average age has been included because it does not take very high values (the average is 39 years and the age distribution ranges between 22 and 50), which indicates that experience may have an important effect on the output. Regarding Sales outside, we consider the firms' proportion of output sold outside of Asturias to control for the fact that the most productive firms are expected to be more able to compete outside local markets. Moreover, the proportion of output with PDO/PGI, is included as an efficiency determinant since we expect that the value added of outputs with these certifications is higher[1]. Finally, we assume that the effect of subsidies on efficiency can also differ between agri-food and forestry firms. Therefore, we include interaction terms for the subsidy variable (s_{it}) and the D_{Agr} and D_{For} dummies.

4. Data

The main objective of the Measure 123, i.e. the improvement in terms of performance of agri-food and forestry firms, is realized by supporting investments that pursue one of the following specific objectives: the application of new production processes or new technologies, the implementation of the use of information technologies, the implementation of quality systems and those aimed at the environmental improvement of the firm. Specifically, in Asturias the Measure 123 was endowed with a total of 70 million euros for the period 2007-2013. This measure usually subsidizes 30 per cent of the approved investment projects (although under certain circumstances the contribution can increase up to 50 per cent of the investment project). The subsidy recipients are microenterprises and small and medium-sized firms (exceptionally, firms that do not exceed 750 employees or 200 million euros in turnover can receive this subsidy), belonging to the agri-food and forestry industries.

The data used in the empirical analysis come from three different sources. First, we include data from the SABI database (Informa, S.A.) corresponding to the outputs and

inputs of agri-food and forestry firms of Asturias in the 2006-2009 period. We consider the amount of sales as output (yit), to which the change in inventories has been added to take into account the total level of output generated during the period, regardless of whether it has been sold. Regarding the inputs, labor (x_{1it}) corresponds to the number of employees; the capital used in the production (x_{2it}) is measured through the depreciation recorded by the firm and, finally, the materials (raw materials and intermediate goods) used to obtain the final output (x_{3it}) are taken from the column recording consumption of the SABI database. SABI also indicates the municipality in which each company is located, allowing us to identify the Central and Coast variables described above.

Second, we carried out a survey of subsidy (through the Measure 123) recipient firms thanks to an agreement with the Principality of Asturias. From this survey, we obtained data related with the ability of firms to perform electronic commerce, the proportion of production with organic certification, the proportion of output with quality certificates in relation to the ISO standard, the average age of the workforce, the proportion of production sold outside of Asturias and the proportion of products with PDO/PGI included in total production.

Finally, the Department of Rural Environment and Fisheries of the Principality of Asturias provided data on the level of subsidies received by the collaborating firms during the period of analysis. This information and the data from the SABI database allowed us to construct the variable s_{it} that measures the proportion that the accumulated level of the subsidies received up to period t represents in the firms' fixed assets. We use the accumulated level of subsidies received up to the corresponding period as we expect that the subsidized investments will have an impact beyond the period they are received. Furthermore, it is standard in the literature to use the ratio of subsidies with respect to some measure related to the volume of the firm's activity (Zhu and Oude Lansink, 2010; De Jorge and Suárez, 2011; Bojnec and Latruffe, 2013), as it is assumed that the impact of a given level of subsidy will depend on the size of the firm.

As discussed above, the period of analysis comprises from 2006 to 2009. While the Measure 123 corresponding to the Rural Development Program 2007-2013 had not been implemented during the first year, i.e. 2006, we include this previous year to control for the evolution of both the production frontier and the level of technical efficiency when firms first receive the subsidy. Regarding the response rate, 76 out of 121 recipient firms responded to the survey, with 53 recipient firms considered in the final database as we excluded those firms with missing variables. Moreover, the final sample is composed by 191 observations as we lack data on several firms in several of the periods considered (as some firms were created after 2006). Table I shows some descriptive statistics of the variables used in the empirical analysis.

The variables measured in monetary units (output, capital and materials) are valued at constant 2009 thousand euros. The deflator used to express the monetary variables in constant terms was the consumer price index. A preliminary analysis of the data shows the high level of heterogeneity for the firms included in the sample. For instance, we observe that the standard deviation for the output and inputs levels volume exceeds the mean of these variables substantially. Moreover, we observe that the database considers not only micro-enterprises with one worker but also medium-sized firms with a maximum of 136 workers. Most of the firms are located in municipalities outside the central zone and in non-coastal areas. Almost half of the companies (46.6 per cent) have quality certification, but very few carry out electronic commerce (6.3 per cent). The proportion of organic production is very low, on average, but it represents an important proportion for those firms producing this type of output.

Variable	Mean	SD	Minimum	Maximum
Output (1000 €)	4,070	7,275	179	48,249
Labor (workers)	20	24	1	136
Capital (1000 €)	112	126	5	533
Materials (1000 €)	2,849	5,910	26	41,378
Subsidy (%)	6.4	8.5	0	34.6
Central (dummy)	0.398	0.491	0	1
Coast (dummy)	0.351	0.478	0	1
Quality certification (dummy)	0.466	0.500	0	1
Electronic commerce (dummy)	0.063	0.243	0	1
Organic (%)	1.8	11.0	0	85
Staff age (years)	39	5	22	50
Sales outside (%)	38.1	33.3	0	100
PDO/PGI (%)	10.4	26.0	0	100
Forestry (dummy)	0.277	0.449	0	1

Source: Own elaboration

Table I.
Sample descriptive statistics

Regarding the inefficiency determinants, the proportion of the cumulative level of subsidies received over the fixed assets shows a high dispersion, with a maximum cumulative level of subsidy of 34.6 per cent. As previously mentioned, the average age of the staff (39 years) is not very high, with its upper limit being relatively low (50 years). Additionally, we observe that, on average, 38.1 per cent of the output is sold outside of Asturias, while only 10.4 per cent of the output has PDO/PGI.

The sample is classified into two main sectors agri-food (72.3 per cent) and forestry firms (27.7 per cent) respectively, according to the activity performed. In Table II, we show the difference in means tests between agri-food and forestry firms for the variables considered in the analysis. The tests indicate that agri-food firms have higher mean values in output, labor and materials, and tend to be located in central and interior areas to a greater extent than forestry firms. Furthermore, forestry firms do not produce goods with organic

Variable	Agri-food mean	Forestry mean	Difference in means test
Output (1000 €)	4,792	2,191	2.39**
Labor (workers)	23	13	2.60***
Capital (1000 €)	112	111	0.47
Materials (1000 €)	3,493	1,173	2.55**
Subsidy (%)	6.4	6.2	0.15
Central (dummy)	0.732	0. 226	7.02***
Coast (dummy)	0.261	0.585	−4.28***
Quality certification (dummy)	0.471	0.453	0.36
Electronic commerce (dummy)	0.057	0.075	−0.48
Organic (%)	2.5	—	—
Age staff (years)	39	41	−3.45***
Sales outside (%)	35.5	44.9	−1.60
PDO/PGI (%)	14.5	—	—

Notes: *Significant at 10%; **significant at 5%; ***significant at 1%
Source: Own elaboration

Table II.
Descriptive statistics based on activity

certification or PDO/PGI, and they show higher mean values in age. However, there are no significant differences in terms of capital variables, subsidies, quality certificates, electronic commerce and sales outside.

5. Results

The input variables were divided by their geometric mean prior to the estimation of equation (3). As a consequence, first-order coefficients reflect the output elasticities of each of the inputs for a representative firm characterized by a level of input equal to the sample geometric mean of each of the inputs. The estimation of equation (3) was performed using maximum likelihood and the econometric software Stata. Table III shows the estimation of the parameters of the production frontier.

Variable	Coef.	*t*-stat
Constant	7.872***	216.10
NACE 220	−0.137***	−4.30
NACE 1011	−0.584***	−28.04
NACE 1013	−0.512***	−17.53
NACE 1051	−0.462***	−22.44
NACE 1089	−1.132***	−14.62
NACE 1102	−0.499***	−5.64
NACE 1103	−0.107***	−2.57
NACE 1610	−0.331***	−8.60
NACE 4120	−0.272***	−6.38
NACE 4622	−0.572***	−11.41
NACE 4631	−0.682***	−26.25
NACE 4632	−0.674***	−19.25
NACE 4639	−0.395***	−12.55
NACE 4673	−0.154***	−5.78
NACE 4722	−0.816***	−28.30
Labor	0.299***	45.52
Capital	0.040***	13.61
Materials	0.695***	79.03
1/2 Labor^2	0.079*	1.84
Labor × Capital	0.047***	3.51
Labor × Materials	−0.059***	−4.19
1/2 Capital^2	0.033	1.28
Capital × Materials	−0.095***	−4.71
1/2 Materials^2	0.107***	9.45
Central	−0.044*	−1.70
Coast	−0.061***	−3.64
Electronic commerce	0.052**	2.38
Organic	0.762***	9.83
Quality certification	0.148***	6.61
D_{2007}	−0.041***	−3.27
D_{2008}	−0.010	−0.58
D_{2009}	−0.009	−0.47
D_{Agr} × subsidy	0.194**	1.99
D_{For} × subsidy	0.001	0.01
Log likelihood	230.579	

Table III.
Stochastic frontier estimation

Notes: *Significant at 10%, **significant at 5%, ***significant at 1%
Source: Own elaboration

Our results show that 31 out of the 35 estimated parameters are significant. As mentioned above, the independent term is associated with the output of firms in group 147 of the NACE classification. All the dummy variables controlling for the different groups of the classification are highly significant, which confirms that the maximum output level for a given input level differs considerably among the different groups considered. The first-order coefficients have the expected signs showing that the representative firm is characterized by significantly positive output elasticities for each of the inputs. We observe that the elasticity of scale for the representative firm (that is, the sum of the first-order coefficients) takes a value of 1.03, being significantly different from 1 at the 1 per cent level of significance, according to the Wald test. That is, this result indicates the presence of increasing returns to scale. The dummy corresponding to 2007 is significantly negative, indicating that the production frontier in that year has shifted downwards in relation to the one observed in 2006. This is an unusual result as it would seem to indicate a technical regress. However, there are two reasons that could justify it. On the one hand, 2007 corresponds to the beginning of the crisis, and the downward shift may reflect this circumstance. On the other hand, the subsidies under the Measure 123 are associated with investment processes, so this negative parameter may show the presence of internal adjustment costs (Lucas, 1967; Treadway, 1970; Mortensen, 1973) related to the beginning of the investment processes. Regarding the main objective of the study, we observe that, in the case of the agri-food industry, subsidies contribute to the upward shift of the production frontier, so they may be playing an important role in facilitating the technical progress of agri-food firms. Regarding forestry firms, we do not find a significant effect for subsidies.

The estimated parameters of equation (4), that is, those related to the efficiency determinants are shown in Table IV.

Five of the seven estimated parameters are significant. The dummy variable that identifies the forestry firms shows a positive sign which indicates that the level of efficiency for these companies is lower, *ceteris paribus* the rest of the variables, than that of the agri-food firms (positive signs imply a greater variance of u_{it}, which translates into a higher expected value for the u_{it} term and a lower expected value for the technical efficiency index).

The staff's average age positively impacts the level of efficiency, which indicates a positive effect related to the workers' experience. We also observe that the higher the proportion of output sold outside of Asturias, the higher the level of efficiency, confirming that the most productive companies are the ones that can compete outside of local markets. In this sense, several studies on exports and their relation to business productivity point to two potential hypotheses by which it is expected that firms that export are more productive than non-exporters (Bernard and Wagner, 1997; Bernard and Jensen, 1999; Girma *et al.*, 2004;

Variable	Coef.	Estad. t
Constant	−1.244	−1.45
D_{For}	1.670***	5.18
$D_{Agr} \times$ subsidy	2.628	1.43
$D_{For} \times$ subsidy	−8.581***	−3.15
Staff age	−0.051**	−2.32
Sales outside	−1.928***	−5.17
PDO/PGI	−2.951***	−5.11

Notes: **Significant at 5%, ***significant at 1%
Source: Own elaboration

Table IV.
Variance of u_{it}

Wagner, 2007). First, the most efficient firms are those that are able to compete outside the local markets, given the additional costs related to the exterior sale process (transport, distribution, creation of external networks, etc.). Second, these firms are exposed to more competitive markets, and this contributes to their learning and to a more intense efficiency improvement than in the case of organizations that only operate in the domestic market.

The proportion of products with PDO/PGI also has positive effects on the efficiency, corresponding, again, with the expected result as these types of products usually present a higher value added. It is often argued that collective brands positively affect the firm's efficiency as economies of scale in production and promotion exist (Tirole, 1988). In this sense, Sellers and Más (2011) explain the positive impact of the collective brand on efficiency because the collective reputation encourages an efficient investment in quality. Moreover, the collective brand may also have an opposite effect on the business incentives because of a "free rider" effect.

In terms of the main objective of the paper, we observe that the effect of subsidies on efficiency is the opposite to that observed on the production frontier. That is, subsidies contribute to improving the technical efficiency of forestry firms but do not have a significant impact on the efficiency of agri-food firms. This differential impact of the subsidies in both sectors highlights the specification bias that would be committed if the model used did not allow for a different estimate of its effect in the two sectors. To show the importance of this differential effect, we include in the Appendix the estimate of the model assuming that the impact of the subsidies is equal for the two sectors considered. The results are very similar for the rest of the variables, but in terms of the impact of the subsidies, one would conclude that this variable only affects production through technical progress, that is, it would not affect the efficiency term.

In this sense, we observe that the result obtained from the subsidies granted under Measure 123 is positive, but it impacts the agri-food and forestry sectors through different channels. These subsidies shift the production frontier for agri-food firms, which seems to correspond to the positive effect of subsidies on investments aimed at the development of new products and processes (one of the specific objectives of Measure 123), this being conducive to an improvement in the productive potential of these firms. In the case of forestry firms, our results, as well as the sectoral reports (Consejería de Empleo, Industria y Turismo del Principado de Asturias, 2015), confirm that investment in machinery and the incorporation of new techniques facilitate a better use of resources. However, a future opportunity has been detected in the development of new processes and products in the forestry sector (European Commission, 2013b).

Finally, we must indicate that our results are relevant for the development of support policies for the sectors analyzed. In this sense, the Rural Development Program of the Principality of Asturias for the period 2014-2020 (Gobierno del Principado de Asturias, 2017) proposes a series of measures to enhance some of the factors that, as seen in this paper, have positive effects both on the production frontier and on the efficiency of agri-food and forestry companies (improvement of the productive structure of companies, promotion of research, innovation and knowledge transfer, cooperation, products with territorial identification, new technologies, improvement in energy efficiency, etc.).

6. Analysis of the return on subsidies

Based on the results obtained, we perform a simulation exercise to assess the return on the subsidies granted under Measure 123. The methodology used, proposed by Jondrow *et al.* (1982), allows us to determine the efficiency scores associated with each one of the

observations of the sample. Table V shows the statistics that characterize the distribution of these efficiency scores.

The companies included in the sample have a relatively high level of technical efficiency. Thus, on average, the actual output is 88 per cent of the maximum achievable if all the productive potential offered by the technology is used.

To examine the effect of the subsidies, the cumulative level of subsidy received at the end of the period has been calculated, resulting in values of 96,568 euros for agri-food firms and 57,290 euros for forestry firms. Once we compute the average subsidy, the expected output value for the agri-food and forestry representative firms has been simulated, defined by the values of the variables included in Table II. Then, two alternative circumstances are simulated:

(1) firms not receiving a subsidy; and

(2) firms in the analysis receiving the average level of subsidy for their sector.

To perform this simulation, we proceed in two steps. First, the production frontier estimate is used to calculate the maximum output level that would be generated by the representative firms of each group[2]. Once we have calculated the output level, the expected level of efficiency is determined. The estimation of the parameters of equation (4) enables the calculation of the logarithm of σ_u which, in turn, allows us to identify the expected level of efficiency (Kumbhakar and Lovell, 2000):

$$E[\exp(-u_{it})] = 2[1 - \Phi(\sigma_u(s_{it}, \overline{z_{hit}}))]\exp\left(\frac{\sigma_u^2(s_{it}, \overline{z_{hit}})}{2}\right) \quad (5)$$

where $\overline{z_{hit}}$ represents the arithmetic mean of the z_{hit} variables and Φ is the standard normal distribution function. With this in mind, it is possible to calculate the expected value of u_{it} for a non-recipient firm and for a firm receiving a subsidy equal to the average corresponding to its group. Consequently, multiplying the output level produced by the efficient firm by the expected level of efficiency, we obtain the expected output level, as shown in Tables VI and VII.

Therefore, the average return on subsidies represents more than 26,000 euros for the representative agri-food firm and 63,000 euros for the forestry firm. Moreover, taking into

Variable	Mean	SD	Minimum	Maximum
Technical efficiency	0.88	0.11	0.50	1

Source: Own elaboration

Table V.
Efficiency scores

Representative firm	Efficient output	Expected efficiency	Expected output
Without subsidy	5,369	0.915	4,911
With subsidy	5,436	0.908	4,935

Source: Own elaboration

Table VI.
Return on subsidies in Agri-food firms

account that the subsidies granted under Measure 123 cover 30 per cent of the subsidized investment, the average cumulative level of subsidies (96,568 and of 57,290 for agri-food and forestry firms, respectively) would correspond to investment projects of 322,000 and 191,000 euros. Consequently, the annual return on these investments would be 8 and 32 per cent for agri-food and forestry firms, respectively.

From the above-mentioned results, we deduce that the implementation of Measure 123 has allowed the recipient firms to undertake investment projects with an important return, especially in the case of forestry firms. In this sense, we can state that this measure has been successful in its objective of improving the firms' performance. An issue beyond the scope of this paper is whether it would have been possible to obtain a similar result with some other type of measure less burdensome for the taxpayer.

7. Conclusions

Income inequalities between urban and rural areas within the EU have led to the implementation of policies aimed at rural development. These types of policies, involving the collaboration of the different administrations of the member states, are articulated around several intervention axes. In particular, the actions planned under Axis 1, including the Measure 123, are aimed at improving the competitiveness of the agricultural and forestry sector.

This paper examines the impact of these subsidies on the firms' technical progress and the technical efficiency. To do so, we estimate a stochastic frontier in which subsidies are allowed to affect both the level of technical efficiency and the technical progress. Our results show a positive effect of the subsidies received on both concepts. From the calculations made, we can conclude that the implementation of the Measure 123 in the Principality of Asturias has allowed investment projects to be undertaken which, in the last period considered in the analysis, would have a rate of return of 8 per cent and 32 per cent for agri-food and forestry firms, respectively. Therefore, the implementation of this measure can be considered successful.

The results of the analysis also show the importance of quality certifications, electronic commerce and the manufacture of organic products in increasing the level of output that an efficient firm can produce. We also find positive effects on the efficiency of the following factors, in addition to the perception of subsidies in forestry firms: the staff's age, sales outside the region and belonging to a PDO/PGI. These are relevant results both for the managers of the firms considered in the study and for public administrations, as they highlight those elements to be strengthened to improve business results. In short, these contribute to maintaining and reinforcing business activity in rural areas (human resources management, opening to foreign markets, electronic commerce, quality certifications and production differentiation). In this sense, the strategies and policies foreseen for the coming years, at regional, national and European level, try to favor these factors in the agri-food and forestry sectors.

Representative firm	Efficient output	Expected efficiency	Expected output
Without subsidy	2,971	0.812	2,413
With subsidy	2,971	0.833	2,476

Source: Own elaboration

Table VII.
Return on subsidies in forestry firms

Finally, it should be noted that, although the incidence of subsidies on the productivity of companies has been studied extensively in the case of agricultural holdings, the number of studies that have analyzed their influence in the case of industrial companies and services through an estimate of production technology is substantially lower.

Notes

1. The PDO/PGI certifications require compliance with certain procedures in the production process, so it could alternatively be considered that this variable would affect the production frontier instead of efficiency. However, since the processes used in this type of products are usually traditional, production techniques do not usually differ between certified production and those which are not. In the case of natural cider, for example, the only difference between the certified production and the uncertified one is the origin of the apple used, while the process of making the product is the same for both types of product. Therefore, we decided to include this variable as a determinant of efficiency rather than as a conditioning variable in the production frontier.
2. For the simulation, we generate different independent terms for agri-food and forestry firms. To do so, we add the parameter β_0 to the average of the parameters β_1 corresponding to the NACE sectors included in each of the two groups of firms. Moreover, the simulation refers to the maximum output obtainable in 2009, so that the dummy corresponding to this year is included in the calculation.

References

Ankarhem, M., Daunfeldt, S., Quoreshi, S. and Rudholm, N. (2010), "Do regional investment grants improve firm performance? Evidence from Sweden", *Technology and Investment*, Vol. 1 No. 3, pp. 221-227.

Bergström, F. (2000), "Capital subsidies and the performance of firms", *Small Business Economics*, Vol. 14 No. 3, pp. 183-193.

Bernard, A.B. and Jensen, J.B. (1999), "Exceptional exporter performance: cause, effect, or both?", *Journal of International Economics*, Vol. 47 No. 1, pp. 1-25.

Bernard, A.B. and Wagner, J. (1997), "Exports and success in German manufacturing", *Weltwirtschaftliches Archiv*, Vol. 133 No. 1, pp. 134-157.

Bernini, C. and Pellegrini, G. (2011), "How are growth and productivity in private firms affected by public subsidy? Evidence from a regional policy", *Regional Science and Urban Economics*, Vol. 41 No. 3, pp. 253-265.

Bojneca, S. and Latruffe, L. (2013), "Farm size, agricultural subsidies and farm performance in Slovenia", *Land Use Policy*, Vol. 32, pp. 207-217.

Calvo-Flores Segura, A., García Pérez de Lema, D. and Madrid Guijarro, A. (2004), "Efectos económicos y financieros de las subvenciones a la inversión en la PYME. Un estudio empírico", *Spanish Journal of Finance and Accounting/Revista Española de Financiación y Contabilidad*, Vol. 33 No. 123, pp. 899-933.

Caudill, S.B., Ford, J.M. and Gropper, D.M. (1995), "Frontier estimation and firm-specific inefficiency measures in the presence of heteroscedasticity", *Journal of Business and Economic Statistics*, Vol. 13 No. 1, pp. 105-111.

Consejería de Empleo, Industria y Turismo del Principado de Asturias (2015), "Estudio sobre la formación y las ocupaciones en el sector forestal y de la madera en el principado de Asturias. Informe de resultados", Servicio Público de Empleo, Gobierno del Principado de Asturias.

De Jorge, J. and Suárez, C. (2011), "Influence of R&D subsidies on efficiency: the case of Spanish manufacturing firms", *Cuadernos de Economía y Dirección de la Empresa*, Vol. 14 No. 3, pp. 185-193.

European Commission (2013a), Rural Development in the European Union, Statistical and Economic Information, Report 2013, available at: http://ec.europa.eu/agriculture/statistics/rural-development/2013/full-text_en.pdf

European Commission (2013b), A new EU Forest Strategy: for forests and the forest-based sector, communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, available at: https://ec.europa.eu/agriculture/sites/agriculture/files/forest/strategy/staff-working-doc_en.pdf

Friedman, M. (1994), "Governments can use incentives rationally", *Economic Development Review*, Vol. 12 No. 4, pp. 25-29.

Girma, S., Greenaway, D. and Kneller, R. (2004), "Does exporting increase productivity? A microeconometric analysis of matched firms", *Review of International Economics*, Vol. 12 No. 5, pp. 855-866.

Gobierno del Principado de Asturias (2017), Programa de Desarrollo Rural del Principado de Asturias 2014-2020, available at: www.asturias.es/portal/site/webasturias/menuitem.a76385ecc651687bd9db8433f2300030/?vgnextoid=f1a07e1385dfe210VgnVCM10000097030a0aRCRD

Guan, Z. and Oude Lansink, A. (2006), "The source of productivity growth in Dutch agriculture: a perspective from finance", *American Journal of Agricultural Economics*, Vol. 88 No. 3, pp. 644-656.

Harris, R. and Robinson, C. (2004), "Industrial policy in great Britain and its effect on total factor productivity in manufacturing plants, 1990-1998", *Scottish Journal of Political Economy*, Vol. 51 No. 4, pp. 528-543.

Harris, R. and Trainor, M. (2005), "Capital subsidies and their impact on total factor productivity: firm-level evidence from Northern Ireland", *Journal of Regional Science*, Vol. 45 No. 1, pp. 49-74.

Harris, R. and Trainor, M. (2007), "Impact of government intervention on employment change and plant closure in Northern Ireland, 1983-1997", *Regional Studies*, Vol. 41 No. 1, pp. 51-63.

Jondrow, J., Lovell, C.A.K., Materov, I.S. and Schmidt, P. (1982), "On the estimation of technical inefficiency in the stochastic frontier production function model", *Journal of Econometrics*, Vol. 19 Nos 2/3, pp. 233-238.

Kumbhakar, S.C. and Lien, G. (2010), "Impact of subsidies on farm productivity and efficiency", in Ball, V., Fanfani, R. and Gutierrez, L. (Eds), *The Economic Impact of Public Support to Agriculture. An International Perspective*, Springer, New York, NY.

Kumbhakar, S.C. and Lovell, K.C.A. (2000), *Stochastic Frontier Analysis*, Cambridge University Press, Cambridge.

Lee, J.W. (1996), "Government interventions and productivity growth", *Journal of Economic Growth*, Vol. 1 No. 3, pp. 391-414.

Lucas, R.E. (1967), "Optimal investment policy and the flexible accelerator", *International Economic Review*, Vol. 8 No. 1, pp. 78-85.

McCloud, N. and Kumbhakar, S.C. (2008), "Does subsidy drive productivity? A cross – country analysis of Nordic dairy farms", in Chib, S., Koop, G. and Griffiths B. (Eds), *Advances in Econometrics: Bayesian Econometrics*, Emerald, Bingley, p. 23.

Martin, J.P. and Page, J.M. (1983), "The impact of subsidies on x-efficiency in LDC industry: theory and an empirical test", *The Review of Economics and Statistics*, Vol. 65 No. 4, pp. 608-617.

Mortensen, D.T. (1973), "Generalized costs of adjustment and dynamic factor demand theory", *Econometrica*, Vol. 41 No. 4, pp. 657-665.

OECD (2001), *Competition Policy in Subsidies and State Aid*, Directorate for Financial, Fiscal and Enterprise Affairs, OECD, Paris.

Piesse, J. and Thirtle, C. (2000), "A stochastic frontier approach to firm level efficiency, technological change, and productivity during the early transition in Hungary", *Journal of Comparative Economics*, Vol. 28 No. 3, pp. 473-501.

Rezitis, A., Tsiboukas, K. and Tsoukalas, S. (2003), "Investigation of factors influencing the technical efficiency of agricultural producers participating in farm credit programs: the case of Greece", *Journal of Agricultural and Applied Economics*, Vol. 35 No. 3, pp. 529-541.

Sellers, R. and Más, F.J. (2011), *Valor de marca colectiva: Aproximación desde el enfoque de la eficiencia*, WP-EC 2011-01, Instituto Valenciano de Investigaciones Económicas, S.A.

Skuras, D., Tsekouras, K., Dimara, E. and Tzelepis, D. (2006), "The effects of regional capital subsidies on productivity growth: a case study of the Greek food and beverage manufacturing industry", *Journal of Regional Science*, Vol. 46 No. 2, pp. 355-381.

Tirole, J. (1988), *The Theory of Industrial Organization*, MA Institute of Technology, Cambridge, EE UU.

Treadway, A.B. (1970), "Adjustment costs and variable inputs in the theory of the competitive firm", *Journal of Economic Theory*, Vol. 2 No. 4, pp. 329-347.

Tzelepis, D. and Skuras, D. (2004), "The effects of regional capital subsidies on firm performance: an empirical study", *Journal of Small Business and Enterprise Development*, Vol. 11 No. 1, pp. 121-129.

Tzelepis, D. and Skuras, D. (2006), "Strategic performance measurement and the use of capital subsidies", *International Journal of Productivity and Performance Management*, Vol. 55 No. 7, pp. 527-538.

Van Tongeren, F.W. (1998), "Microsimulation of corporate response to investment subsidies", *Journal of Policy Modeling*, Vol. 20 No. 1, pp. 55-75.

Wagner, J. (2007), "Exports and productivity: a survey of the evidence from firm-level data", *The World Economy*, Vol. 30 No. 1, pp. 60-82.

Zhu, X. and Oude Lansink, A. (2010), "Impact of CAP subsidies on technical efficiency of crop farms in Germany, The Netherlands and Sweden", *Journal of Agricultural Economics*, Vol. 61 No. 3, pp. 545-564.

Further reading

Council Regulation (CE) (2019), Council Regulation (CE) n° 1698/2005 of 20 September of 2005 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD).

Appendix

Variable	Coef.	*t*-stat
Constant	7.847***	140.51
NACE 220	−0.102***	−2.59
NACE 1011	−0.571***	−9.36
NACE 1013	−0.497***	−8.33
NACE 1051	−0.463***	−8.98
NACE 1089	−1.097***	−16.53
NACE 1102	−0.530***	−5.67
NACE 1103	−0.084	−1.32
NACE 1610	−0.298***	−5.90
NACE 4120	−0.279***	−4.20
NACE 4622	−0.542***	−7.86
NACE 4631	−0.658***	−12.94
NACE 4632	−0.643***	−10.60
NACE 4639	−0.376***	−4.71
NACE 4673	−0.149***	−2.87
NACE 4722	−0.803***	−16.53
Labor	0.306***	33.93
Capital	0.038***	4.26
Materials	0.696***	106.56
1/2 Labor^2	0.123***	2.79
Labor × Capital	0.034*	1.95
Labor × Materials	−0.075***	−3.60
1/2 Capital^2	0.064***	5.11
Capital × Materials	−0.099***	−5.93
1/2 Materials^2	0.115***	14.01
Central	−0.048**	−2.06
Coast	−0.075***	−15.91
Electronic commerce	0.142***	8.72
Organic	0.063***	3.22
Quality certification	0.761***	8.97
D_{2007}	−0.044***	−6.38
D_{2008}	−0.010	−1.06
D_{2009}	−0.012	−0.99
Subsidy	0.194***	3.70
Log likelihood	225.947	

Table AI.
Stochastic frontier estimation

Notes: *Significant at 10%, **significant at 5%, ***significant at 1%
Source: Own elaboration

Variable	Coef.	*t*-stat
Constant	−0.892	−1.01
D_{For}	1.181***	4.42
Subsidy	0.204	0.15
Staff age	−0.055**	−2.52
Sales outside	−2.016***	−5.91
PDO/PGI	−3.086***	−5.39

Notes: **Significant at 5%, ***significant at 1%
Source: Own elaboration

Table AII.
Variance of u_{it}

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