Discover Sustainability

Research

The effect of subsidies on tecnical efficiency of Algerian agricultural sector: using stochastic frontier model (SFA)

Houari Moulay Ali[1] · Mohammed Seghir Guellil[1] · Fayçal Mokhtari[1] · Abderrahmane Tsabet[1]

Received: 19 February 2024 / Accepted: 13 May 2024
Published online: 23 May 2024

Abstract
This study seeks to determine the impact of agricultural subsidies on the efficiency of Algerian farms. To do so, we estimated a Stochastic Frontier Analysis (SFA) for Algerian data covering the period from1970 to 2020. Two variables were used to describe the agricultural subsidy: the first is total agricultural support, and the second is a dummy variable that takes the values 0 and 1 to express the coupling of subsidies to production. The variable of support for agriculture production and producers takes the value of one (1) in the era when the support is not related to production (decoupled support). It takes the value zero (0) when there is explicit support for production and producers (coupled support).The findings revealed that total subsidies had a negative impact and statistically significant on the technical efficiency of Algerian farms. While, the decoupling has a positive effect on efficiency (negative on inefficiency), but without significance.

Keywords Agricultural support · Coupled support · Decoupled support · Technical efficiency · Stochastic Frontier Analysis (SFA) · Algeria

JEL Classification H21 · H71 · O13 · Q18 · C51

1 Introduction

Algerian government support for the agriculture began in the early 1970s and was explicitly adopted in 1983. According to [1] « The explicit support policy for agriculture and farmers did not appear until 1982, and it was applied in 1983». This was through state support for the prices of production factors (inputs and agricultural equipment). In 1989, under Resolution No. 12/89, production factors support has been removed in favor of production support, the guaranteed minimum price is the main instrument for doing so. Agricultural price guarantees accounted for the largest share of agricultural subsidies (87 percent of the total support in 1991, and 78.8 percent for the period 1989–1994). After the Standby Agreement with the International Monetary Fund in 1995, all forms of support came to an end.

The year 2000 witnessed the return of state support to the agricultural sector through the National Plan for Agricultural Development (it is the same policy to this day), through a variety of measures and in several domains (price support on production, input support, investment and agricultural equipment support……).When compared to subsidizing production and producers' incomes, investment support, especially the acquisition of water resources and agricultural equipment, is predominant on the state's expenditures to support the sector. According to estimates [2], «the agricultural

✉ Houari Moulay Ali, houari.moulay@univ-mascara.dz; Mohammed Seghir Guellil, m.guellil@univ-mascara.dz; Fayçal Mokhtari, faycal.mokhtari@univ-mascara.dz; Abderrahmane Tsabet, tsabet.abderrahmen@univ-mascara.dz | [1]Faculty of Economics, Business and Management Sciences, MCLDL Laboratory, University of Mascara, 29000 Mascara, Algeria.

Discover

support during the period of the national agricultural development plan reached 750 euros per farm, more than 60 percent of this support is directed towards water resource mobilization, the producer support estimate (PSE)—percentage of total revenue—up to 5 percent in the 2005–2006 season». Also, the total support to the agricultural sector are weak and represent 9.1 percent of the value-added of the agricultural sector and less than 1 percent of GDP in 2004 (0.84 percent) [3]. As a result, the state's support for the agricultural sector is relatively minimal, and the measures that can distort production and trade represent only a small percentage, and therefore it is permissible and excluded from the WTO commitment.

The total support for the agricultural sector in the period (2010–2014) amounted to 1000 billion DA, 600 billion DA (6.1 billion euros) was allocated to the agricultural side, this represents 120 billion DA annually (1.22 billion euros, about 0.9 percent of GDP), and 400 billion DA was allocated to the rural side.

Historically, the performance of the agricultural sector (output) in Algeria was positively related to government transfers, mainly represented in different forms of agricultural support, whether this support is related to production (coupled subsidies), or is it not related to production in the form of public investments and input support (decoupled subsidies), for example, after the 1989 reform, which eliminated subsidies to factors of production, the prices of most of the necessary inputs and means of production have grown at very high rates: the fertilizer price index reached 648 in 1992 (95 in 1983), the tractor price index reached 1062 in 1992 (100 in 1983), the rest of the products have witnessed nearly the same rate of price growth. This increase had a detrimental influence on the usage of these intermediate consumptions, which affected the agricultural sector negatively.

The 1996–97 season was defined by a 24 percent decrease in agricultural production, this was mostly due to the elimination of various forms of subsidies in 1995, which led to a decrease in the supply of fertilizers and other inputs [4].

The reintroduction of support during the years 2000 led to an increase in production in response to various forms of this support at very high rates, so that from 1999 to 2018, agricultural production in Algeria increased by 574.7 percent.

1.1 Given this favorable impact on agricultural production, what effect do support measures have on the technical efficiency of Algerian farms?

While the subject has been investigated on a large scale, whether theoretically or empirically (panel or cross-sectional data), there has been no study of the impact of subsidies on efficiency in the framework of the state of Algeria, or in the context of North African countries, or even the countries of Mena. It is also an open experimental matter [5, 6]. And, in many cases, the effect (positive, negative, significant and insignificant) changes as the study sample, time period, and method of study change [7]. Therefore, it is not possible to rely only on theoretical evidence, not even the findings of previous studies, and this should be applied to the case of Algeria.

2 Literature review

The subsidies may influence production in several ways: by changing the relative prices of inputs and outputs; by affecting income and thus changing on- and off farm labour supply; by affecting income and therewith investment decisions; and by influencing farm growth and exit. All these effects may change the technical and economic performance on the farms [6].

Theoretically, the negative impact of subsidies on efficiency and productivity is linked to many factors, the most notable of which is the encouragement of subsidies to slacken, give more leisure time and reduce productive efforts by farmers if a large portion of a farmer's income is assured by subsidies, as a result such productive efforts to increase efficiency are no longer requied, this is known as the wealth (income) effect [8]. Argue that Farmers' efforts in farming activities may be reduced if a larger part of their income is guaranteed by subsidization. Subsidization may enable farmers to smooth their wealth without adopting efficient production strategies. Subsidies may also lead to soft budget constraints, causing inefficient use of resources. According to [9] if the budget constraint is soft such productive efforts are no longer imperative. Instead, the firm is likely to seek external assistance asking compensation for unfavorable external circumstances. The state is acting like an overall insurance company taking over all the moral hazards with the usual well-known consequences, the insured will be less careful in protecting his wealth. If however, the constraint is hard, the firm has no other option but to ajust to unfarorable circumstances, it must behave in an entrepreneurial manner.

The negative impact of subsidies is also related to distortions in the use of factors of production: subsidies give recipient farms an incentive to over-invest in subsidized inputs which can lead to allocative inefficiency [10], and it can provide an incentive to farmers to use less input [6].[1]

The negative impact of subsidies is also related to distortions in production structure, farms may change their behavior and start looking for investing in subsidized activities that are less productive [11].

Subsidy payment increases efficiency if the subsidies provide an incentive to innovate or to switch to new technologies. The positive impact of subsidies may be due to investment-induced productivity gains caused by interactions of credit and risk attitudes with subsidies (subsidy-induced credit access, lower cost of borrowing, reduction in risk aversion, increase in productive investment) [10]. Subsidies can reduce the risks faced by farmers by increasing their wealth (wealth effect) and making them less risk-averse and therefore produce more. Risk effect can also work through insurance effect, which reduces the price risk faced by domestic producers and therefore lead to increase production [12].

Theoretical studies suggest that subsidies may have a positive impact on farm production and at the same time a negative impact on farm productivity [10]. However, the sign of the effect of subsidies on efficiency cannot be determined by a priori theorizing, and the effect of subsidies on technical efficiency is an open empirical question [5, 6].

The impact of public subsidies on farm technical efficiency has been investigated empirically in a number of research. A meta-analysis of empirical results on the impact of public subsidies on farm technical efficiency presented by [8], they showed that the most common findings on this issue, subsidies are commonly negatively associated with farm technical efficiency [8]. Have argued that: When non-significant relationships are not considered, the effect of subsidies on technical efficiency is significantly negative for 71 percent of the models and significantly positive for 29 percent. When taking into account the cases where subsidies have no significant effect, the effect is significantly negative for 60 percent of the models, significantly positive for 24 percent of the models and non-significant for 16 percent. The direction of the observed effects is sensitive to the way that subsidies are modelled in the empirical studies.

The negative impact of subsidies on technical efficiency was found by [5], for data about Ghana's logging and saw-milling industries, the findings clearly support the hypothesis that subsidies reduce the level of relative efficiency of recipient firms.

The negative impact of subsidies on farms' technical efficiency was found by [13] for an unbalanced panel data set of 100 wheat farms in Saskatchewan from 1987 to 1995, found that efficiency is negatively related to government income transfers [14]. Used English and Welsh farm-level survey data from 1982 to 2002 to estimate stochastic frontier production functions for eight different farm types (cereal, dairy, sheep, beef, poultry, pigs, general cropping, and mixed). Negative effects was found for cereal, sheep, general cropping and mixed farms meaning that the higher the proportion of gross margin that is derived from subsidies the lower is farm efficiency. Dairy and beef farms were found to have positive effects. By using data from Dutch arable farms [15], show that the subsidies have a significant negative impact on productivity. In addition, a strong significant negative relationship between managerial efficiency and CAP direct payments found by [16] for French COP and beef farms in 2000. The negative impact of subsidies on farms' technical efficiency was also found by [17], but, that subsidies are positively associated to farm profitability.

Contrary to the studies mentioned above, other studies have found a positive effect of agricultural subsidies on technical efficiencyand productivity [18]. Used an unbalanced panel data for Danish, Finnish, and Swedish dairy farms and partition the data into eight regions. The data set covers the period 1997–2003, they found that subsidies have a positive impact on technical efficiency. The study of [6] based also on an unbalanced panel data from Norwegian grain farms during 1991–2006, showed that subsidies negatively affected farm productivity but had a positive influence on technical efficiency. The subsidies in this last study are treated as an endogenous variable in productivity and inefficiency models, whereas, in almost all studies, subsidies are treated as exogenous. In this latter model, Subsidies are treated as "facilitating inputs" defined as "inputs that are not necessary for production. Subsidies are expected to affect not only technical efficiency but also the technology itself, a formulation that has no theoretical basis according to [7].

By using stochastic frontier model [19], argued that subsidies of the investment character provided within the Rural Development Programme of the Czech Republic obtained in the framework of the CAP for years 2007–2013 have a positive and statistically significant impact on the technical efficiency.

Farm gross investment is positively associated with public investment subsidies, according to [20].

[1] [48] By using a stochastic frontier approach, Proved that empirically. they indicated that subsidies lead to excess use of labor relative to capital and excess use of fuel relative to capital and labor.

Estimating the effects of Common Agricultural Policy investment support on farm performance indicators for Swedish farms from 2007 to 2016 by [21], the farm perfomance measured as annual growth in labour productivity, TFP, employment and turnover. The findings revealed that, with the exception of employment, investment support has a favorable impact on all variables.

Regarding the viewpoint that subsidies could lead to soft budget constraints, causing inefficient use of resources, and Contrary to what [9] referred to, [22] based on farm data from three Russian regions from 1999 to 2003, has shown that the budget constraints caused on average, a potential output loss of 20 per cent. Output loss due to technical inefficiency, on average, is found to be around 13 per cent [23]. Showed that subsidies have significant welfare impacts since it alleviate the credit constraint and hence reduce inefficiencies in the economy.

Recent studies have concentrated on the modern trend of subsidies, which includes decoupling subsidies from production decisions and distorting trade, and showing the impact of each type of subsidies (coupled and decoupled) on efficiency and productivity of farms. The large part of studies focused on investigation of the effect of the CAP Reforms related to decoupling. The general consensus is that switching to decoupled subsidies will improve efficiency, and most empirical investigations back this up.

Starting with [24], who concluded that the new payment regime for the European Union's Common Agricultural Policy, which was adopted in June 2003, will encourage farmers who choose to produce to allocate more land to riskier products than previously. This policy will decouple from production all direct payments made to farmers.

Zhu et al. [25] analysed the impacts of subsidies Under the CAP reforms on technical efficiency of crop farms. The model is applied for the period (1995–2004) in Germany, Netherlands and Sweden. The study indicates that the subsidies (coupled subsidies) have a much smaller effect on efficiency than the subsidy's income component. In which, the effects of coupled subsidies to crop production (the share of crop subsidies in the total subsidies) on efficiency are ambiguous (positive in Sweden, negative in Germany, and an insignificant impact in the Netherlands). The results also showed that in all countries studied, the share of total subsidies in total farm revenues (the income and insurance effect) has a significantly negative impact on technical efficiency.

Mary et al. [26] used panel data from a large sample of French crop farms observed between 1996 and 2003 to estimate Cobb–Douglas production functions. The study indicated that several CAP subsidies have a negative impact on farm total factor productivity (TFP). The CAP reforms through Agenda 2000 (decoupling) have had a positive impact on TFP in French crop farms. Also, [10] studied the impact of CAP subsidies on TFP, using data from the EU-15 countries. The findings emphasise the negative effect of subsidies on farm productivity prior to the implementation of the decoupling reform. After decoupling the effect of subsidies on productivity is more nuanced and in several countries it turned positive.

Banga et al. [12] used Data Envelopment Analysis (DEA) to examine the impact of Green Box subsidies (in principle decoupling subsidies) on agriculture productivity and technical efficiency in 26 countries from 1995 to 2007. Green Box subsidies increased agricultural productivity by around 60 percent in the EU and 51 percent in the USA over this time period, according to the findings.

Fayçal et al. [27] used the ARDL approach to analyze data from Algeria, the results indicated that the support of agriculture production and producers (coupled subsidies) has a positive impact on the agricultural growth, while it has a negative impact on the economic growth in the long term. On the other side, the total agricultural support regardless of its relationship with production and producers (decoupled) has a positive impact on agricultural production growth and economic growth in the long term.

Even though, the subsidies were decoupled, the negative impact was found by [28], the authors examined the relationship between agricultural subsidies and farm efficiency using data for dairy farms. The analysis covers the period going from 1990 to 2007 and includes the following seven countries: Denmark; France; Germany; Ireland; Spain; the Netherlands; and the United Kingdom. Higher subsidy are found to be significantly associated with higher technical inefficiency across all seven countries. Besides, the most recent Common Agricultural Policy (CAP) regime, which included decoupled payments, has reduced technical efficiency in all countries studied except for Denmark.

Exploring the relationship between the subsidy policy and the agricultural total factor productivity (TFP) in China's cotton production, Even when subsidies are related with acreage, [29] found that agricultural TFP will be reduced when the subsidy policy is enacted, and that there is a negative relationship between the subsidy and TFP.

Other studies have found that the effect is negligible, [30] showed that the production effect of decoupled payments is negligible [7], by using an original method of moments estimator and accounting for endogeneity, argued that the effect of subsidies on technical efficiency might be positive, null, or negative, depending on the country. The analysis shows that decoupling, which was implemented with the 2003 CAP reform, weakens the effect that subsidies have on technical efficiency. In other words, after the introduction of decoupling, the relationship between subsidies and technical efficiency does not change direction (it remains positive or negative) but it becomes weaker.

3 Data and empirical strategy

3.1 Model

We usually distinguish between non-parametric and parametric approaches when measuring technical inefficiency. Non-parametric techniques are typically used in the DEA (Data Enveloppement Analysis) method, which allows the efficiency frontier to be built using mathematical optimization models and linear programming techniques. The parametric methods that have been integrated to the SFA method (Stochastic Frontier Analysis): it is an alternative approach to the estimation of frontier functions using econometric techniques.

This approach was used by [31] who considered a Cobb–Douglas production frontier of the form:

$$\ln Y_i = \beta_0 + \sum_{i=1}^{n} \beta \ln X_i - U_i \; ; \quad U_i \geq 0 \tag{1}$$

where Y_i denotes the output the i-th firm; X_i denotes the vector of inputs; β is a vector of unknown parameters; and U_i denotes a non-negative random variable related to technical inefficiency.

The problem in the model above is that no account is taken of mesurement errors and other sources of statistical noise- all deviations from the frontier are assumed to be the result of technical inefficiency. So that the production frontier is deterministic (non-stochastic) quantity exp(X_iB) [32].

An obvious solution to the problem is to introduce another random variable representing statistical noise by [33, 34]. The resulting frontier is known as a stochastic production frontier [32].

The Cobb–Douglas function to be estimated becomes:

$$\ln Y_i = \beta_0 + \sum_{i=1}^{n} \beta \ln X_i + v_i - \mu_i \; ; \quad \mu_i \geq 0 \tag{2}$$

where v_i is normally distributed noise. We also suppose that there is a vector z_i of exogenous variables that influence the level of μ_i.

The v_i are assumed to be iid $N(0, \sigma_v^2)$ random errors, independently distributed of the μ_i.

The underlying idea behind SFA is to introduce an additive error term, which has tow components (a noise and an inefficiency term). Distributional assumptions have to be made for both the error term and the inefficiency term. The most common assumption is the half normal distribution, but some studies assume a number of alternative distributions for the inef fi ciency error component. These include the exponential, truncated normal, and gamma distributions [35]. The properties of the truncated normal distribution seem more realistic than those of the half-normal distribution [36].

Stochastic production frontier model used in this study is that of [37], in a stochastic frontier model, the technical inefficiency effect, V_i can be expressed using the following equation (Eq. 3) presented by [37]:

$$\mu_i = \delta Z_i + w_i \tag{3}$$

where i is the firm (i = 1,2………N); Zi denotes the vector of explanatory variables associated to technical inefficiency of production of firms over time; δ denotes the vector of unknown coefficients. The random variable, w_i is defined as the truncation of a normal distribution with zero mean and varianceσ^2, so that the point of truncation is $-Z_i\delta$.

We also suppose that w_i is independent of v_i.

For simultaneous estimate of the parameters of the stochastic frontier and the model for technical inefficiency effects, the maximum likelihood method is proposed.

The likelihood function is expressed in terms of the variance parameters, the parameters associated with $v_i and \mu_i are$:

$$\sigma^2 = \sigma_\mu^2 + \sigma_v^2 \;\; and \;\; \gamma = \sigma_\mu^2 \Big/ \left(\sigma_\mu^2 + \sigma_v^2 \right) \tag{4}$$

The following equation defines the technical efficiency of production:

Table 1 Summary statistics of the input and output variables (n = 50)

Variable	Label	mean	Std. dev	Min	Max
Agr. Value-added per worker (const 2010 USD) *	Y	8131.25	5751.96	1801.50	20889.02
Gross fixed capital formation (constant 2010 USD)(10^9) *	K	36	26.9	9.1	97.6
Total Labor (Employed population) **	L	5959915	2969064	1983200	11300000
Utilised agricultural land (10^3 hectare) *	LAND	7923.76	478.59	6800	8565.4
Total support of the agricultural sector (Expenditures for the agriculture and irrigation sector per hectare)(10^3 DZD) ***	TS	10,16	13,91	0,059	46,88
Agriculturale use of fertilizers by Nutrient; N, P205, K20 (kg per hectare) ****	NPK	18,25	7,67	4,72	37,36
Education (The number of graduates from universities) **	EDUC	87373.76	110938	817	393908

Source: * WDI; ** Office for National Statistics (ONS); *** Financial laws; **** FAOSTAT

$$TE_i = \exp(-u_i) = \exp(-Z_i\delta - w_i) \tag{5}$$

u_i is predicted by the conditional mean estimator, $u_i = E\{u_i/\varepsilon_i\}$ Kumbhakar and al [46];

Where; $\varepsilon_i = v_i - u_i$

Battese et al. [37] employed a method known as the "one-step" model, which specifies both the stochastic frontier and the way in which u depends on z, and can be estimated in a single step, for example using maximum likelihood [38].

The "one step" method was created to address the "two step" method's bias issue. It has long been recognized that such a two-step procedure will give biased results,[2] because the model estimated at the first step is misspecified. Two-step procedure where the first step is to estimate a standard stochastic frontier model, and the second step is to estimate the relationship between u and z [38].

Other models that employed the same model as [37] include the [39] model and the [40] model.

3.2 Data and variables

For Algerian annual data, we estimated the SFA model described above. The model's variables have been chosen for the period 1970–2020 based on what is included in the literature, In addition to the available data for the case of Algeria. Because the objective is to investigate the Algerian case. It is noticeable that. There are no studies studied the subject of the impact of agricultural policies on efficiency in the context of Algeria and North African countries in recognized databases. We hoped to use a sample that included North African or at least Arab countries, but data constraints forced us to chose Algeria, where no statistical bodies supply data for a sufficient number of farms, preventing us from applying the model to cross-sectional data, as a result, annual data was used. The lack of an adequate model for our data (the offered models are either for panel data or cross-sectional data), that lead us to treat the data from each year as a separate observation to be used to compare the efficiency in that year with other years. We use the cross sectional model and run it with our data with the assumption that the time series is a cross-section. Each year will be treated as separate.

The descriptive statistics for the variables in the model are presented in Table 1. The mean value of agricultural value added per worker is 8131.25 USD, with the lowest value being 1801.5 USD and the highest being 20889.02 USD. The mean of the capital equal 36 billion dollars (the lowest value is 9.1 billion dollars and the highest value 97.6 billion dollars). In Algerian agriculture, the average total labor force is 5.96 million workers (1.98 million workers as the minimum value and 11.3 million workers as the maximum value). The minimum and maximum arable areas are 6.8 million hectares and 8.6 million hectares, respectively. In terms of the factors that explain inefficiency, the average yearly Total support of the agricultural sector per hectare of arable land is 10160 DZD (about 75 dolar), with the lowest value being 59 DZD and the greatest value being 46880 DZD (357 dolar). For agricultural fertilizer consumption by nutrient, the average is 18.25 kg per hectare of nutrients (the minimum is 4.72 kg per hectare and maximum 37.36 kg per hectare). Finally, the mean of the period equals 87373.76 garduates for the education variable, which is given as the number of graduates from universities.

[2] To understand the reasons why this method is deemed biased, as you can see [38] and [47].

We estimate a Cobb–Douglas stochastic production frontier, the stochastic frontier production fonction to be estimated is;

$$lny_i = \beta_0 + \beta_1 \ln(K) + \beta_2 \ln(L) + \beta_3 \ln(LAND) + v_i - \mu_i$$

The technical inefficiency effects is given by;

$$U_\mathrm{i} = \delta_0 + \delta_1(TS) + \delta_2(PS) + \delta_3(NPK) + \delta_4(EDUC) + w_i$$

We estimate a Cobb–Douglas stochastic production frontier, the stochastic frontier production fonction to be estimated is;

$$lny_i = \beta_0 + \beta_1 \ln(K) + \beta_2 \ln(L) + \beta_3 \ln(LAND) + v_i - \mu_i$$

The technical inefficiency effects is given by;

$$U_\mathrm{i} = \delta_0 + \delta_1(TS) + \delta_2(PS) + \delta_3(NPK) + \delta_4(EDUC) + w_i$$

Our model draws inspiration from Battese and Coelli's [37] approach. In determining the stochastic frontier production, we've employed classic explanatory variables, consistent with prior studies like [41] and Battese and Coelli [37], including Labor, capital, and agricultural land.

What sets our model apart from others, such as Battese and Coelli [37], is our use of fertilizers by nutrient. While they typically use nutrient-specific fertilizers to determine the production frontier, we've instead incorporated it as an independent variable in our model of technical efficiency. This decision was influenced by the historical context of fertilizers by nutrient use in Algerian agriculture, which is closely tied to the support it receives. In instances where there is a lack of support for fertilizers by nutrient, their use tends to decline. Therefore, we've included it in the technical efficiency model to explore how fertilizers by nutrient impact efficiency, given their financial and moral link to support measures. Currently, fertilizer fertilizers by nutrient support in Algeria stands at 50% of the price.

The agricultural subsidy is represented by two variables, the first variable is total agricultural support (ST), which comprises expenditures related to agriculture and irrigation. The second variable is support for production and producers (SP). This last is a dummy variable to express the coupling of subsidies to production, this variable takes the values 0 and 1. In the era when the support is not related to production, the variable of support for agriculture production and producers takes the value of one (1) (decoupled support).When there is explicit support for production and producers, it takes the value zero (0) (coupled support).

Decoupling dummy variable equal to one (1) for the period (from 1970 to 1982 and 1995 to 1999) (it is the period when the support is not related to production), and zero (0) otherwise.

Many studies, similar to OECD studies that distinguish between subsidies paid to producers (producer support) and total agricultural support, employ annual government expenditures for the agricultural sector to express total agricultural support. This last includes the total expenditures or the total support to the agricultural sector regardless of its relationship to production and producers. The first type of subsidy is more related to production and distortion of trade, it is about the state transfers to agricultural producers, including market price support, transfers related to the level of output, related to the use of inputs, and other subsidies linked to some products.

We considered the periods without support for production and producers, taking into account: During the years 1970–1982, [1] confirmed that «It was not until 1982 that explicit support for agriculture and farmers was introduced, and it has been in place since 1983», Therefore, prior to 1982, there was no support policy for production and producers, even if there was some support at the price level for some factors of production used in agriculture during this time, however, this support does not reflect a political intention to support producers, given the low pricing of agricultural products established by the government, which is not entirely supportive of production and producers.

The second period (1995–1999): this is the period when agricultural subsidies were completely eliminated, after the Stand-By agreement with the International Monetary Fund.

For periods of state support for producers are (1983–1994) and (2000–2020) these are periods of explicit support backed by a political desire for agricultural production and producers.

Given that agricultural development hinges on investments in research and technical assistance [42], we've included education as an explanatory variable in our model of technical efficiency. Education can potentially stimulate innovation and the adoption of new techniques in agriculture. We've used the number of graduates from Algerian universities as a proxy for education and the development of research in Algeria, which undoubtedly part of it is directed to agriculture. Numerous studies, such as those by [37, 43–45] have also included education as an explanatory variable for technical efficiency in the SFM model, highlighting its importance across various contexts.

4 Econometric results and analysis

The results of the stochastic frontier estimation are shown in the equations below, and the calculations were done in the software Stata 16.0.

Stochastic Frontier:

$lnY =$	$-22,96$	$+0,11\ln(K)$	$+1,02\ln(L)$	$+1,51\ln(LAND)$	$+v_i - \mu_i$
	()	(0, 002)	(0, 0003)	(0, 004)	

Inefficiency Model:

$U_i =$	0.189	$+0.017(TS)$	$-0,10(PS)$	$+0,002(NPK)$	$-0,0000043(EDUC)$	$+w_i$
	(0, 11)	(0, 005)	(0, 07)	(0, 004)	(0, 0000012)	

The sign of stochastic frontier was as expected for all variables, with positive and significant effects for all factors that explain agricultural labor productivity: capital, labor, and utilized agricultural land, with elasticities of 0.11, 1.02, and 1.51, respectively. As the model shows, the biggest impact comes from the side of Utilized agricultural land.

The estimated coefficients in the inefficiency model are very low (except for the variable of decoupling). Additionally, the sign of some variables contradicts our expectations, particularly in the case of total agricultural support and Fertilizers by Nutrient (NPK), which have positive and significant signs (Which negatively affect efficiency). It has the following elasticities: 0.017 for total agricultural support per hectare, and 0.002 for Agricultural use of fertilizers by Nutrient per hectare. The decoupling variable and the education variable have a positive effect on efficiency (negative on inefficiency), but without statistical significance, and their elasticities are 0.1 and 0.0000043, respectively.

4.1 Hypothesis testing

Central to the stochastic frontier model is the one-sided error specification which represents technical inefficiency. It is therefore important to test the existence of the one-sided error for the model. If evidence for the one sided error specification is not found, the model then reduces to a standard regression model for which a simple OLS estimation would suffice [46]. Testing hypothesis about frontier parameters to test the absence of inefficiency effects; in the case of trucated normal model the null hypothesis of no inefficiency effects is $H_0 : \mu = \sigma_\mu^2 = 0$, it is possible to test for inefficiency effects using Wald, *LM* and *LR* tests, the one-sided nature of the alternative hypothesis implies these tests are difficult to interpret, they don't have the asymptotic chi-square distributions [32, 37]. Shows that the *LR* test statistic is asymptotically distributed as a mixture of chi-square distributions. The critical values of the mixed distribution for hypothesis testing are tabulated in table of Kodde and Palm (1986).

This amounts to a test for the presence of μ_i in the model, and a generalized likelihood ratio (LR) test for the null hypothesis of no one-sided error can be constructed based on the loglikelihood values of the OLS (restricted) and the SF (unrestricted) model.

The LR test statistic is;

$$-2\left[L\left(H_0\right) - L\left(H_1\right)\right]$$

where $L\left(H_0\right)$ and $L\left(H_1\right)$ are log-likelihood values of the restricted model (OLS) and the unrestricted model (SF), respectively.

At the 1% significance level, the LR test statistic = 33.37 exceeds the critical value of the statistic, which is equal to 11.911.[3] As a result, we reject the null hypothesis that there are no inefficiency effects.

[3] The LR test would have 6 degrees of freedom; five for mu and one for usigma functions.

Table 2 Summary TE

Variable	Mean	Std. Dev	Min	Max
TE	0.86	0.096	0.53	0.99

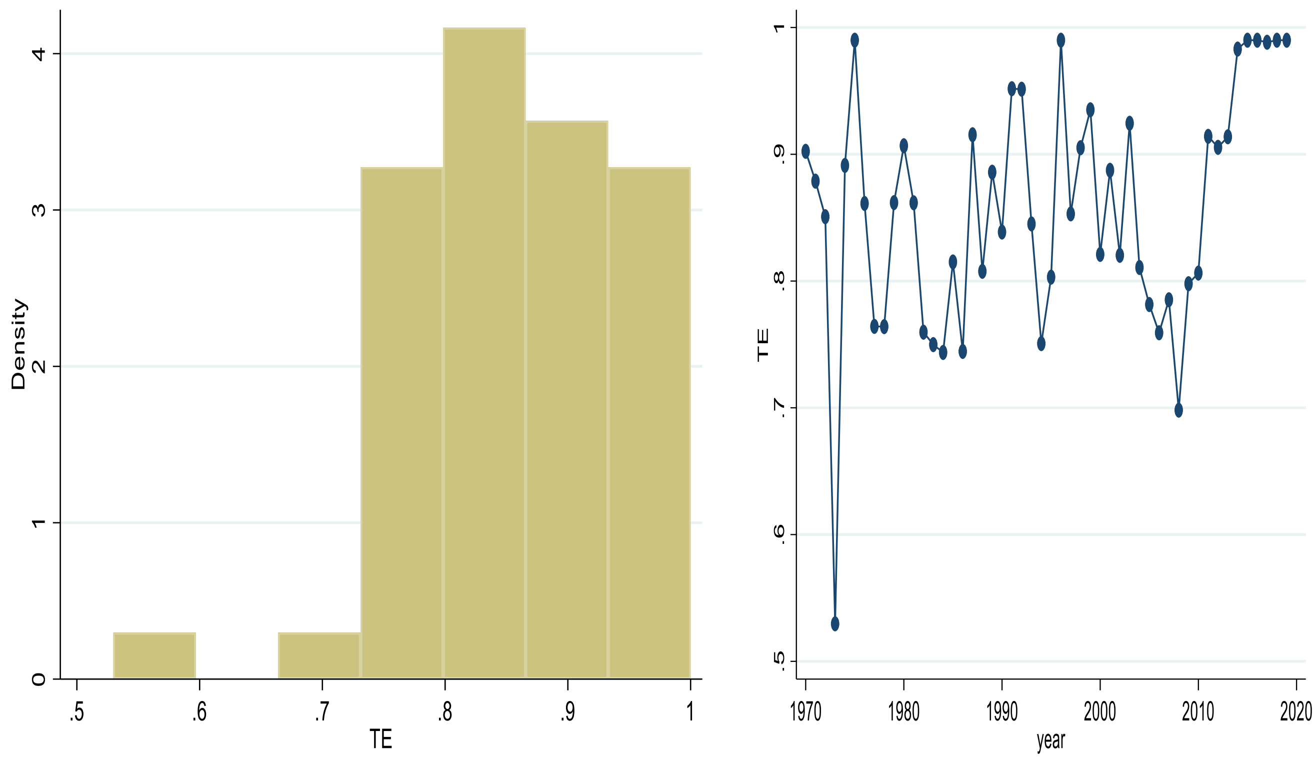

Fig. 1 The efficiency index

Another statistic also serve as a test of the existence of the one-sided error, is the gamma parameter, However, sometimes misused, the ratio, should not be interpreted as the share of total model variation attributable to the inefficiency variation, since the variance of the one-sided error (u) is not equal to σ_u^2 [46]. $\boldsymbol{\gamma} = \frac{\sigma_u^2}{\sigma^2}$**;** The ratio has a value between 0 and 1, If gamma close to one indicates that the inefficiency effects are highly significant in the analysis of the value of the output. This estimate (=0.98) is high, meaning that much of the variation in the composite error term is due to the inefficiency component. That means that 98% of the total variation from the maximum production(frontier)related to inefficient error term and 2% of the total variation is due to the stochastic random errors.

We can also test if the technical inefficiency has a half- normal distribution. The null hypothesis is that the simpler half-normal is adequate, $H_0 : \mu = 0$ and the alternative hypothesis that the technical inefficiency has a truncated normal distribution is $H_1 : \mu \neq 0$. The statistic of the test is also the LR test mentioned above; Where $L(H_0)$ is the log-likelihood value of the restricted model (half-normal).

The LR test statistic = 4.17, exceeds the critical value $\mathcal{X}^2_{0,95}(1) = 3,84$. That means, we reject the null hypothesis that the half-normal is adequate.

4.2 The efficiency index

We can estimate the degree of efficiency of each observation in the data, measuring the level of efficiency (or inefficiency) considered one of the most important indicators of the SF model. The method for estimating this indicator is shown in the above Eq. (5).

Descriptive statistics of the estimated technical efficiency index of the agricultural sector in Algeria are given in the Table 2.

The mean of TE equals 0.86, implying that, on the average, the Algerian agricultural sector produce 86% of the maximum output, or that it lost about 14% of the output due to technical inefficiency.

Below, the histogram and curve of efficiency index (Fig. 1); The oscillation in the Technical Efficiency Index in Algerian agriculture is evident from 1970 to 2010. Technical efficiency has seen a gradual and continuous decrease from 1970 to 2010, with levels ranging from 0.70 to 0.90, and recording values outside this range in a few years. For example, in 1973, it recorded 0.52, which is the lowest value recorded for the Technical Efficiency Index in Algerian agriculture. In 1999, it recorded 0.99, which is the highest level recorded over the period, and this year was the exception before 2010. Technical efficiency started to increase from 2010, stabilizing at 0.99 from 2014 onwards.

5 Conclusion

The study seeks to determine the impact of agricultural subsidies on the efficiency of Algerian farms. To do so, we estimated a Stochastic Frontier Analysis (SFA) for Algerian data from 1970 to 2020. The lack of an adequate model for our data (the offered models are either for panel data or cross-sectional data), that lead us to treat the data from each year as a separate observation to be used to compare the efficiency in that year with other years. We use the cross sectional model and run it with our data with the assumption that the time series is a cross-section. Each year was treated as separate. Stochastic production frontier model used in this study is that of [37].

The agricultural subsidy was expressed in two variables: the first is total agricultural support, and the second is a dummy variable that takes the values 0 and 1 to express the coupling of subsidies to production. The variable of support for agriculture production and producers takes the value of one (1) in the era when the support is not related to production(decoupled support). It takes the value zero (0) when there is explicit support for production and producers (coupled support).

The results indicated that total subsidies had a negative impact and statistically significant on the technical efficiency of Algerian farms. While, the decoupling have a positive effect on efficiency (negative on inefficiency), but without significance. The rest of the findings revealed that Fertilizers by Nutrient has a negative and significant impact on farm technical efficiency, while education has a positive and insignificant impact.

The majority of the empirical research in this field as well as the current theoretical framework are supported by the study's findings [10]. Confirms that theoretical studies suggest that subsidies could have a favorable effect on agricultural output while simultaneously having an adverse effect on farm productivity.

The study's empirical findings are in line with 71% of research that looked at how subsidies affect technical efficiency. According to [8], when non-significant relationships are not considered, the effect of subsidies on technical efficiency is significantly negative for 71 percent of the models.

Also, the findings of most research support the notion that productivity and technical efficiency would benefit from a move toward less coupled subsidies, and our study's results are no different.

The study backs up the negative impact of support on technical efficiency, which is a term associated with the efficiency of using production factors. This might be the result of the government bearing heavy costs, which could have an impact on agricultural productivity and the overall state of the economy. Or it could be the moral component of support policies, as farmers may become lazier as a result of depending on it and guaranteeing a sizeable portion of income from it.

Additionally, when production and support are coupled, it could lead to market instability because farmers may act illegally to take advantage of the support or because the measure's heavy monitoring burdens and adversely affects market functioning. The study also indicates the negative impact of fertilizer use on technical efficiency, as it also costs the state large amounts, considering that fertilizer use in Algeria is linked to expenses borne by the state, as 50% of its expenses are borne by the state in the form of subsidies.

The study's findings are consistent with the trend toward decoupling subsidies from production decisions, as they interfere less with production choices, distortion of trade, and interfere less with functioning of markets. Therefore, it is imperative for the government to formulate subsidies policies that primarily focus on decoupled subsidies, so minimizing decisions about output, prices or even consumption that are associated with subsidies.

Author contributions All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version. Moulay Ali Houari (A) and Mokhtari Fayçal

(C) focused more on the theoretical aspect of the subject and chose the most suitable model. Guellil Mohammed Seghir (B) and Tsabet Abderrahmane (D) were more concerned with the applied study and model estimation.

Data availability The data used for each variable can be found in: Agr. Value-added per worker; Gross fixed capital formation; and Utilised agricultural land can be found in World Bank Indicators (WDI): https://donnees.banquemondiale.org/indicator. Total Labor; and Education (The number of graduates from universities) can be found in Office for National Statistics (ONS): https://www.ons.dz. Total support of the agricultural sector (Expenditures for the agriculture and irrigation sector per hectare) can be found in Algeria's Financial laws: https://www.mf.gov.dz/index.php/fr/textes-officiels/lois-de-finances/101-lois-de-finances Agriculturale use of fertilizers by Nutrient; N, P205, K20 (kg per hectare) can be found in FAOSTAT: https://www.fao.org/faostat/en/#home For the material we used the software Stata 16.0.

Declarations

Competing interests The authors declare no competing interests.

References

1. S. Bedrani, N. Boukhari et A. Djennane, «Eléments d'analyse des politiques de prix, de subvention et de fiscalité sur l'agriculture en Algérie. Options Méditerranéennes. 111, pp. 121–149, 1997.
2. Soutiens et subventions agricoles. FILAHA: le site agriculture, http://www.filaha.net.
3. Bedrani S. L'agriculture, l'agroalimentaire, la pêche et le développement rural en Algérie. In: Allaya M, editor. Les agricultures méditerranéennes: analyses par pays. Montpellier: CIHEAM; 2008. p. 37–73.
4. Chaouki B. Les Politiques de développement agricole: le Cas de l'Algérie: impact du PNDA PNDAR sur le développement économique. Thèse de doctorat. Es Senia: Université d'Oran-Sénia; 2011. p. 504.
5. Martin JP, Page JM. The impact of subsidies on X-efficiency in LDC industry: theory and an empirical test. Rev Econ Stat. 1983;65(4):608–17.
6. Kumbhakar SC, Lien G. Impact of subsidies on farm productivity and efficiency. In: Eldon Ball V, Fanfani R, Gutierrez L, editors. The economic impact of public support to agriculture. New York: Springer; 2010. p. 109–24.
7. Latruffe L, et al. Subsidies and technical efficiency in agriculture: evidence from European dairy farms. Am J Agric Econ. 2017;99(3):783–99.
8. Minviel JJJ, Latruffe L. Effect of public subsidies on farm technical efficiency: a meta-analysis of empirical results. Appl Econ. 2017;49(2):213–26. https://doi.org/10.1080/00036846.2016.1194963.
9. Kornai J. The soft budget constraint. Kyklos. 1986;39:3–30.
10. Rizov M, Pokrivcak J, Ciaian P. CAP subsidies and productivity of the EU farms. J Agric Econ. 2013;64(3):537–57.
11. Alston JM, James JS. The incidence of agricultural policy. Handb Agric Econ. 2002;2:1689–749.
12. Banga, Rashmi. Impact of green box subsidies on agricultural productivity, production and international trade. Working Paper, 2014. researchgate.net.
13. Giannakas K, Schoney R, Tzouvelekas V. Technical efficiency, technological change and output growth of wheat farms in Saskatchewan. Can J Agric Econ. 2001;49(2):135–52.
14. Hadley D. Patterns in technical efficiency and technical change at the farm-level in England and Wales, 1982–2002. J Agric Econ. 2006;57(11):81–100.
15. Zhengfei G, Lansink AO. The source of productivity growth in Dutch agriculture: a perspective from finance. Am J Agric Econ. 2006;88(3):644–56.
16. Laure Latruffe, Herve Guyomard, Chantal Le Mouël. The role of public subsidies on farms' managerial effciency: an application of a five-stage approach to France. [University works] auto-saisine. 2009, 25p
17. Bojnec Š, Latruffe L. Farm size, agricultural subsidies and farm performance in Slovenia. Land Use Policy. 2013;32:207–17.
18. McCloud N, Kumbhakar SC. Do subsidies drive productivity? A cross-country analysis of Nordic dairy farms. Adv Econ. 2008;23:245–74.
19. Pechrova M. Impact of the rural development programme subsidies on the farms' inefficiency and efficiency. Agric Econ. 2015;61(5):197–204.
20. Fertö I, Bakucs LZ, Bojnec S, Latruffe L. East-West European farm investment behaviour: the role of financial constraints and public support. Span J Agric Res. 2017;15(1):e01SC01.
21. Nilsson P, Wixe S. Assessing long-term effects of CAP investment support on indicators of farm performance. Eur Rev Agric Econ. 2021. https://doi.org/10.1093/erae/jbab038.
22. Kumbhakar SC, Bokusheva R. Modelling farm production decisions under an expenditure constraint. Eur Rev Agric Econ. 2009;36(3):343–67.
23. Ciaian P, Swinnen JFM. Credit market imperfections and the distribution of policy rents. Am J Agric Econ. 2009;91(4):1124–39.
24. Roche MJ, McQuinn K. Riskier product portfolio under decoupled payments. Eur Rev Agric Econ. 2004;31(2):111–23.
25. Zhu X, Lansink AO. Impact of CAP subsidies on technical efficiency of crop farms in Germany, the Netherlands and Sweden. J Agric Econ. 2010;61(3):545–64.
26. Mary S. Assessing the impacts of pillar 1 and 2 subsidies on TFP in French crop farms. J Agric Econ. 2013;64(1):133–44.

27. Fayçal M, Ali HM. Economic growth and government subventions for agriculture sector in Algeria: an ARDL model. Arab Econ Business J. 2016;11(2):105–14.
28. Laure Latruffe, Boris E. Bravo-Ureta, Victor H. Moreira, Yann Desjeux, Pierre Dupraz. Productivity and subsidies in European Union countries: an analysis for dairy farms using input distance frontiers. 13. EAAE Congress: "Change and Uncertainty Challenges for Agriculture, Food and Natural Resources", European Association of Agricultural Economists (EAAE). INT., Aug 2011, Zurich, Switzerland. 16 p. ffhal-01462637
29. Tan Y, Guan J, Karimi HR. The impact of the subsidy policy on total factor productivity: an empirical analysis of China's cotton production. Math Probl Eng. 2013. https://doi.org/10.1155/2013/248537.
30. Henningsen, Arne, Subal C. Kumbhakar, and Gudbrand D. Lien. Econometric analysis of the effects of subsidies on farm production in case of endogenous input quantities. No. 319–2016–9639. 2009.
31. Aigner DJ, Chu S-F. On estimating the industry production function. Am Econ Rev. 1968;58(4):826–39.
32. Coelli TJ, et al. An introduction to efficiency and productivity analysis. Berlin: Springer science & business media; 2005.
33. Aigner D, Knox Lovell CA, Schmidt P. Formulation and estimation of stochastic frontier production function models. J Econom. 1977;6(1):21–37.
34. Meeusen W, van Den Broeck J. Efficiency estimation from Cobb-Douglas production functions with composed error. Int Econ Rev. 1977. https://doi.org/10.2307/2525757.
35. Heshmati A, Kim J. Stochastic frontier production function model specification and estimation results. In: Heshmati A, Kim J, editors. Efficiency and competitiveness of international airlines. Singapore: Springer; 2016. p. 75–121.
36. Lévêque, Julien, and William Roy. "Quelles avancées permettent les techniques de frontière dans la mesure de l'efficience des exploitants de transport urbain?." XIVèmes journées du SESAME: Séminaire d'Etudes et de Statistiques Appliquées à la Modélisation en Economie, 23, 24 et 25 septembre 2004, UPPA: Université de Pau et des Pays de l'Adour, CATT: Centre d'analyse théorique et de traitement des données économiques. 2004.
37. Battese GE, Coelli TJ. A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empir Econ. 1995;20(2):325–32.
38. Wang H-J, Schmidt P. One-step and two-step estimation of the effects of exogenous variables on technical efficiency levels. J Prod Anal. 2002;18(2):129–44.
39. Kumbhakar SC, Ghosh S, McGuckin JT. A generalized production frontier approach for estimating determinants of inefficiency in U.S. dairy farms. J Business Econ Stat. 1991;9:279–86.
40. Huang CJ, Liu J-T. Estimation of a non-neutral stochastic frontier production function. J Prod Anal. 1994;5(2):171–80.
41. Wang J, et al. A method for estimating output elasticity of input factors in Cobb-Douglas production function and measuring agricultural technological progress. IEEE Access. 2021;9:26234–50.
42. Nadia C. Population growth and agriculture in poor countries: a review of theoretical issues and empirical evidence; world development. Print Great Br. 1997;25(7):1151–63.
43. Luh Y-H. The impact of education on agricultural productivity: evidence from East Asian economies. Int J Food Agric Econ (IJFAEC). 2017;5(4):11–24.
44. Alene AD, Manyong VM. The effects of education on agricultural productivity under traditional and improved technology in northern Nigeria: an endogenous switching regression analysis. Empir Econ. 2007;32(1):141–59.
45. Reimers M, Klasen S. Revisiting the role of education for agricultural productivity. Am J Agr Econ. 2013;95(1):131–52.
46. Kumbhakar SC, Wang H, Horncastle AP. A practitioner's guide to stochastic frontier analysis using Stata. Cambridge: Cambridge University Press; 2015.
47. Schmidt P. One-step and two-step estimation in SFA models. J Prod Anal. 2011;36(2):201–3.
48. Sakano R, Obeng K, Azam G. Subsidies and inefficiency: stochastic frontier approach. Contemp Econ Policy. 1997;15(3):113–27.