Adoption of Cocoa Certification Scheme and Farmer's Technical Efficiency in Cameroon: A Double Bootstrap Procedure

This is a preprint that has been submitted to Journal of Productivity Analysis

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Journal of Productivity Analysis

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--Manuscript Draft--

Manuscript Number:	PROD-D-23-00073
Full Title:	Adoption of cocoa certification scheme and farmer’s technical efficiency in Cameroon Lékié Division: A double bootstrap procedure
Article Type:	S.I. : Efficiency, Productivity and Economic Growth in Africa
Keywords:	Certification adoption; Technical efficiency; Cocoa; Double-bootstrapped DEA procedure; Cameroon
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Funding Information:	

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Abstract

In a bid to promote the adoption of certification schemes in the cocoa subsector, this study used data collected from 100 cocoa farmers applied on the two-stage double bootstrap data envelopment analysis (DEA) procedure to estimate the bias-corrected technical efficiency scores of cocoa producers with respect to the level of adoption of the Rainforest Alliance/UTZ cocoa certification scheme in the Centre region of Cameroon. The result indicates that yields per hectare remain low for cocoa farmers but is highest for partial adopters, followed by complete adopters and non-adopters; inefficiency remains rampant amongst cocoa farmers but declines as one moves from non-adoption to partial and then complete adoption. However, partial adoption appears to be more favourable for technical efficiency relative to complete adoption in the short run. Moreover, inefficiency is highest for non-adopters as their respective ages and the year of their experience increase. Likewise, non-adopters and partial adopters with secondary or higher level of schooling tend to be less efficient than complete adopters with similar level of schooling. This study therefore shows that the level of adoption of certification schemes matter for farmers' technical efficiency. Hence certification bodies and agricultural extension programs should promote the adoption of certification schemes and encourage farmers to adopt the certification norms progressively and move from non-adoption to partial adoption in the short run and then to complete adoption in the long run.

Keywords: Certification adoption, Technical efficiency, Cocoa, Double-bootstrapped DEA procedure, Cameroon.

JEL Codes: Q18, Q5, Q13.

1. Introduction

Cocoa is one of the main sources of foreign exchange earnings several African countries such as Cameroon, Cote d'Ivoire, and Ghana (Danso-Abbeam and Baiyegunhi, 2020). In Cameroon, the world's fifth-largest producer (Lescuyer and Bassanaga, 2021), cocoa is the country's main export crop, currently cultivated on area estimated at 600,000 hectares of arable land (Lescuyer et al., 2019).

Cocoa is produced seven of the ten regions of Cameroon namely the Centre, South, East, South-West, Littoral, North-West and East regions (ONCC, 2015) mostly by smallholders on farm plots of about 2–3 ha (Assoua et al., 2022). Providing more than 80% of the national output, the Center and South-West regions are the two main cocoa producers in Cameroon (Lescuyer et al., 2019). However, today, most cocoa orchards in the country are aging and witnessing a decline in productivity, while environmentally friendly practices being wiped out (Jaza Folefack and Darr, 2021) and the quality of cocoa beans produced has become a major call for concern among stakeholders (Assoua et al., 2022). It is in an attempt to overcome these challenges that cocoa certification has been launched in Cameroon since 2012.

Certification schemes have recently gained recognition and popularity among consumers of coffee, bananas, other staple crops and cocoa (Paschall and Don Seville, 2012). Three cocoa certification systems are currently in place throughout Cameroon; Chronologically, the Rainforest Alliance system, the UTZ standard and the Fairtrade and Organic systems (Jaza and Darr, 2021; Nlend Nkott et al., 2019). Since 2018, the UTZ and Rainforest Alliance certification programs have partnered to promote responsible cocoa production that benefits the producer and the market through a merger.

Certification aims at remedying the expected shortages and resolve sustainable development-related issues (Kuit and Waarts, 2015). Rainforest Alliance/UTZ requires producers to respect certain agricultural practices as well as social and environmental criteria and helps cocoa producers to practise agricultural systems that protect the environment (Jaza Folefack and Darr, 2021; Nlend Nkott et al., 2017). It compounds on prior education, the farmer's age and its experience in crop production. Firstly, education helps farmers to easily acquire competences offered by programs. Secondly, youth are the best target as they constitute the greatest share of labour force in developing countries and upraising their production is a good path to sustain their commitment in the agricultural sector. Finally, experience in production allows the deconstruction of inefficient and consolidation of good production practices, which permits new efficient production methods to last.

The new organisation resulting from the Rainforest Alliance-UTZ merger as well as its new certification mechanism, retain the name 'The Rainforest Alliance' and in this new Rainforest Alliance certification system, buyers of certified cocoa are compelled to pay at least 70 dollars per ton as premium (Carimentrand, 2020). Farmers operating with the Rainforest Alliance/UTZ certification schemes benefit from several advantages such as supervision, information and training on good agricultural practices'; donations of agricultural equipment and inputs; a premium of 50 CFAF per kg of cocoa sold to the certified firm; and part of the income derived of certified cocoa sales is invested in collective infrastructure in the farmers' villages concerned (Lescuyer et al., 2019).

In spite of all the facilities provided by certification schemes, in 2016, certified cocoa represented only 3% of national cocoa production (Ngoucheme et al., 2016) and rose to 24% in 2019 (Lescuyer and Bassanaga, 2021). Hence, certification remains underdeveloped in Cameroon (Nlend Nkott et al., 2019) and ordinary alongside certified cocoa beans are both being produced in Cameroon (Suh et al., 2020). The participation of smallholders remains very low in Cameroon because they cannot meet the sustainability standards imposed by certification systems, this because of the ageing nature of their plantations, their small sizes, insulation and lack of material resources. In addition, the price and premium for certified cocoa are far too low to convince producers to invest in improving their production techniques (Lescuyer and Bassanaga, 2021).

Certification can generate a wide range of benefits to farmers as well as buyers along the supply chain. Although the emphasis varies from one certification scheme to another, certification as a whole aims at generating economic, social and environmental benefits to farmers (Paschall and Don Seville, 2012). Empirical analysis reveal that farmers involved in cocoa certification schemes enjoy higher cocoa yields (Brako et al., 2021; Iddrisu et al., 2020; Ngoucheme et al., 2016), higher profit margins (Ngoucheme et al., 2016), higher farm and household incomes and profits (Gockowski et al., 2013; Iddrisu et al., 2020; N'dri Allou, 2016). Also, in literature there are several pathways through which adoption of certification schemes can boost farmer's performance. The producers' levels of education and fertiliser application are some of the factors influencing participation in certification to improve the cocoa yield and profit margin (Ngoucheme et al., 2022).

There exist a handful of empirical studies on the contribution of the farmer's participation in cocoa certification schemes and the adoption of good agricultural practices on farm or production efficiency (Brako et al., 2021; Carimentrand, 2020; Danso-Abbeam et al., 2020; Danso-Abbeam and Baiyegunhi, 2020; Gockowski et al., 2013; Iddrisu et al., 2020; Tabi et al., 2017; Tothmihaly and Ingram, 2019). However, these studies are mostly focused on Ghana, Indonesia and little is known about Cameroon which is the world's fifth-largest producer of cocoa. This study therefore comes in as one of the first to ascertain the technical efficiency implications of the farmer's adoption of the Rainforest Alliance/UTZ certification scheme in Cameroon with the use of Data Envelopment Analysis (DEA) and truncated regression estimations with double bootstrap.

Cocoa certification requires certain standards and norms and may therefore be regarded as a process and an outcome. Extensive studies have been conducted on the adoption of cocoa certification and its potential effects. However, most studies (Ansah et al., 2020 ; Brako et al., 2021 ; Fenger et al., 2017 ; Jaza Folefack et al., 2021 ; Ngoucheme et al., 2016 ; Nlend Nkott et al., 2019) have considered adoption/participation in certification schemes a dichotomous parameter with two options: certified or non-certified (has adopted or has not adopted) or consider the frequency of attendance to certification training sessions (Iddrisu et al., 2020).

However, it has been long accepted that adoption of most agricultural technologies involves a non-binary process and tends to be partial and incremental (Brown et al., 2017). As Brown et al., indicate, employing a dichotomous classification of adoption may limit understanding of how a technology fits within the contextual constraints of the community. Hence, adoption of cocoa certification mechanisms may be viewed as a process wherein farmers gradually adjust their production systems to conform to requirements of the certification schemes. Having this in view, this study views participation in certification schemes as a process and conceptualises adoption of the certification as no-adoption, partial adoption and complete adoption.

With an in-depth evaluation of the fall outs of voluntary certification schemes, it is possible to conclude on the necessity of extending certification to more producers and adopting it as a governance system for a sustainable cocoa sector. Hence, the objectives of this study are to ascertain the level of adoption of the Rainforest Alliance/UTZ cocoa certification scheme in the Centre region of Cameroon; evaluate the technical efficiency of cocoa producers with respect to their level of adoption of the Rainforest Alliance/UTZ certification scheme; and unearth the short run and long-run effects of the adoption of cocoa certification schemes on cocoa farmers' technical efficiency. The rest of the paper is structured as follows: Section 2 presents the methods used in this study. Section 3, the results obtained. Finally, section 4 presents the conclusions and policy implications.

2. Methodology

2.1. Study Area

This study is carried out in the centre region of Cameroon. It is the main cocoa producing region in Cameroon accounting for close to 50% of national cocoa output (Lescuyer et al., 2019). The Mbam and Inoubou and Mbam and Kim divisions of the centre region precisely are chosen for the study because of the enthusiasm that exists in these two divisions in regards to certified cocoa, all the exporters of these divisions provide assistance to the producers in groups with respect to cocoa certification requirements.

The Mbam and Inoubou and Mbam and Kim divisions together make up what is commonly called the *grand Mbam*. It is located in the Center region of Cameroon between 4° and 6° latitude North and 10° 5 and 12° longitude East. It covers a surface area of 34,600 km2 with an average temperature of 24° C and a heavy reliance on agriculture as main income generating activity.

2.2. Data collection

The field work was carried out between March and May 2022 in the Mbam and Inoubou and Mbam and Kim divisions of the centre region of Cameroon. The survey was carried out in 10 of the 14 subdivisions that make the Mbam and Inoubou and Mbam and Kim divisions. A multistage sampling technique was employed to select farmers for the survey. At the first stage, ten (10) subdivisions were purposively selected namely; Makenen, Deuck, Ndikinimeki, Kon-Yembetta, Bafia, Bokito and Ombessa (under the Mbam and Inoubou division), then Ngoro, Ntui and Mbangassina (under the Mabm and Kim division). These subdivisions were selected based on the growing interest of farmers in modernising their cocoa orchards in these zones. At the second stage, 10 cocoa farmers were randomly selected from each of the subdivisions. At the end of the process, 100 cocoa farmers were selected, 70 from Mbam and Inoubou and 30 from Mbam and Kim divisions respectively.

Table 1: Distribution of surveyed cocoa farmers by division and subdivision

Division	**Subdivision**	**Number of farmers**
Mbam and Inoubou	Makenene	10
	Deuck	10
	Ndickinimeki	10
	Kon-Yambeta	10
	Bafia	10
	Bokito	10
	Ombessa	10
Mbam and Kim	Ngoro	10
	Ntui	10
	Mbangassina	10
Total		100

2.3. Analytical framework

This study mainly evaluates the effects of cocoa farmers' adoption of rainforest/UTZ certification standards on farm technical efficiency. The existing body of literature on adoption of innovations mostly builds on dichotomous/binary classifications to analyse adoption that is, a farmer can be either an 'adopter' or 'non-adopter' (Brown et al., 2017). This approach has been widely used in analysing the farmer's adoption of and participation in cocoa certification schemes (see (Ansah et al., 2020; Fenger et al., 2017; Jaza Folefack et al., 2021; Ngoucheme et al., 2016; Nlend Nkott et al., 2019). However, such a framework provides limited insight and can lead to misleading conclusions.

In this study, adoption of cocoa certification mechanisms is therefore viewed as a process wherein farmers gradually adjust their production systems to conform to requirements of the certification schemes or they apply the certification standards some but not all farm plots. Having this in view, this study views participation in certification schemes as a process and conceptualises adoption of the certification as no-adoption, partial adoption and complete adoption. Brown et al. (2017) note that partial adoption is rarely adequately recognised or quantified in the literature. This study therefore comes in as one of the few that takes into account partial adoption in its analysis.

Also, the peculiarity of this study is that besides considering adoption as a process, it examines the technical efficiency implications of the farmer's participation in the Rainforest Alliance/UTZ certification scheme with the use of the Data Envelopment Analysis (DEA) and a truncated regression estimation which unearths the short – and long-term implications of cocoa adoption with respect to the level of adoption.

2.4. Empirical specifications

The aim of this paper is to analyse the effects of the adoption level of certified cocoa on the technical efficiency of producers in the Centre Region of Cameroon. The study uses a double bootstrap procedure. This methodological approach is in advance on similar studies analysing technical efficiency in sub-Saharan Africa (Danso-Abbeam et al., 2020; Danso-Abbeam and Baiyegunhi, 2020; Djoumessi et al., 2018; Ndiaye and Bayompe Kabou, 2021; Sawadogo et al., 2022; Tabi et al., 2017; Telleria and Marco, 2022) and Asia (Ho et al., 2022; Panpluem et al., 2019; Sabroso and Tamayo, 2022).

Based on the approach of Simar and Wilson Simar and Wilson (2007), the paper uses truncated regression estimation with double bootstrap to test the significance of explanatory variables in the second stage for several reasons: First, the true score of efficiency is not directly observable. Rather, it is estimated empirically. Second, the two-stage DEA method also depends on other explanatory variables that are not considered in the first-stage efficiency estimation. This means that the error term should be correlated with the second-level explanatory variables. Third, the domain of efficient scores is restricted to the 0 to 1 interval, which should be considered in the second stage of estimation (Danso-Abbeam and Baiyegunhi, 2020; Jebali et al., 2017).

2.5. Technical efficiency estimation with DEA approach

Technical efficiency is a common method used to evaluate the performance of a decision-making unit (DMU) against best practice constraints. Efficiency scores are key performance indicators or indicators of success and are used to evaluate production units. In the literature, there are two estimation techniques for calculating technical efficiency: Nonparametric DEA and Parametric Stochastic Production Frontier (SPF). The DEA method uses linear programming to estimate farm unit (DMU) efficiency in a way that packs the observed input-output factors as tightly as possible (Lee et al., 2009).

A stochastic production frontier model, also known as technical inefficiency, measures the ratio between actual and expected maximum production given inputs and technology. The stochastic frontier model also recognises that fluctuations in maximum output can result from random shocks such as climatic conditions, beyond the control of production units. Output imbalances can also result from farmers operating at varying levels of inefficiency due to weak incentives, inadequate management, inadequate input levels, or imperfect competition (Battese and Rao, 2002).

In this study the nonparametric linear programming frontier procedure is applied at the expense of the parametric statistical method for two reasons. First, DEA avoids the problem of misspecifying the production function. Second, the double bootstrap DEA approach proposed by Simar and Wilson (1998, 2000, 2007) allows to determine the statistical properties of nonparametric limit estimators.

There are two main types of DEA in the literature: input-oriented and output-oriented. For an assumed input level and output level, the output-oriented maximises the output without further expanding the input, while the input oriented minimises the input level to achieve the same output level. Our analytical units are cocoa growers who have more control over the inputs used in their production than their outputs. Therefore, we apply an input-oriented method to measure the efficiency value of agricultural units. The determination of the input-oriented method was also motivated by Coelli et al. (2005), who suggests that the orientation to use should come from the part of the production system that the unit of analysis has more control over.

A number of empirical studies (Ogada et al., 2014; Rahman and Awerije, 2015) use input-oriented approaches to estimate farm-level performance in sub-Saharan Africa. An input-oriented DEA was applied to estimate household technical efficiency of cocoa farmers in Ghana (Danso-Abbeam and Baiyegunhi, 2020). However, their study did not correct for bias in measuring technical efficiency values using the double bootstrap DEA method, causing the estimated efficiency scores to be overestimated. This study therefore follows some previous work (Danso-Abbeam et al., 2020; Fragkiadakis et al., 2016; Jebali et al., 2017; Li et al., 2021; Poudel et al., 2015) and estimate technical efficiency using the DEA approach. This can be expressed as:

$$\begin{aligned} &\theta Z_k' - Z_k'\lambda \geq 0 \\ &Y'\lambda \geq Y_k \qquad (1) \\ &\lambda \geq 0 \end{aligned}$$

Following Simar and Wilson (2007), the efficient level of input $\theta Z_k'$,is defined as the projection of a jth cocoa farm manager on the efficient frontier. The scalar, θ denotes the efficiency score of the k^{th} cocoa farmer, satisfying the condition: $\theta \leq 1$, and λ denotes the I x 1 vector of constant. The z x n and m x n indicate the input (Z') and output matrix (Y'), respectively. Z_k denotes a vector of inputs employed, and Y_k is the output of the k^{th} cocoa farm.

Eq. (1) represents the constant return-to-scale (CRS), also known as overall technical efficiency (OTE_{CRS}), suggesting that farmers operate on an optimal scale OTE_{CRS}. This consists of two components: the pure technical efficiency (PTE), which represents the management practices under the assumption of variable return-to-scale (VRS), hence denoted as PTE_{VRS} and the residual called the scale efficiency (SE) (Latruffe et al., 2008; Ullah and Perret, 2014).

Following Banker et al. (1984), the addition of the constraint $\sum\lambda_k = 1$. Eq. (1) gives rise to the VRS frontier. SE is the ratio of OTE to PTE (SE = OTE/PTE) and measures the scale of operations of the farm. Nevertheless, farms usually experience increasing or decreasing return-to-scale (IRS or DRS, respectively). Hence, Cooper et al. (2007) proposed a non-increasing return-to-scale (NIRS) model where a constraint $\sum\lambda_k \leq 1$ is added to Eq. (1). Comparing $OTE_{CRS}$and TE_{NIRS} indicates whether a farm unit is experiencing IRS or DRS. If $1 > OTE_{CRS} < TE_{NIRS}$, then a cocoa farm is considered inefficient, where the inefficiency is due to IRS. In contrast, if $1 > OTE_{CRS} < TE_{NIRS}$, then the farm's inefficiency emanates from the DRS (Wossink and Denaux, 2006).

However, the focus of DEA technique is to measure DMU efficiency. It is unable to explain the difference in efficiency. In other words, the DEA does not compute factors that explain differences in technical efficiency ratings among DMUs. Therefore, a second-level approach of regressing the efficiency estimate ($\hat{\theta}$) onto a vector of explanatory variables should be used, as suggested by many studies (Dhungana et al., 2010; Sharma et al., 1999; Wadud and White, 2000). A number of empirical studies (Mohapatra and Sen, 2013; Poudel et al., 2015; Wossink and Denaux, 2006) use Tobit regression for the second stage of the DEA, with the assumption of censored distribution error terms since the dependent variable ($\hat{\theta}$) ranges between zero (0) and one (1).

Nevertheless, this famous approach has been criticised because of the potential bias in the efficiency scores. While the DEA analysis assumes no statistical noise, there is uncertainty because efficiency scores are sensitive to measurement and sampling errors. These sampling errors can occur because DEA constructs boundaries from the sample rather than from the population. Furthermore, Simar and Wilson (2007) found that efficiency values estimated by DEA are highly interdependent. Therefore, they violate the underlying assumptions of the regression model and can make the censored regression model unsuitable. Therefore, Simar and Wilson (2007) proposed a statistically correct double bootstrap estimation procedure that allows consistent inferences while producing standard errors and confidence intervals for efficiency scores. The idea of bootstrapping is to mimic the true sampling distribution by simulating the data generation process (Badunenko and Mozharovskyi, 2016). Bootstrapping is a necessary condition in the 'absence of a statistical underpinning' Greene (2008). Therefore, in this study, we used a double bootstrap estimation procedure in which the error term is truncated rather than censored. This procedure is implemented using Stata 16 software (Badunenko and Tauchmann, 2019). Using the double bootstrap procedure of Simar and Wilson (2007), the truncated maximum likelihood (ML) can be expressed as :

$$\hat{\theta}_k = \zeta * \text{Adop} + z_k\beta + \varepsilon_k \qquad (2)$$

where $\hat{\theta}_k$ represents the efficiency score of each DMU, Adop is the vector of interest variables (adoption), ζ is the unknown parameter related to the interest variable, z_k denotes the vector of control variables, β is the set of unknown parameters, and ε_k is the error term $N(0;\ \sigma^2)$ with left-truncated $1 - z_k\beta$.

Previous studies modelled efficiency under the assumption of CRS (Färe et al., 1994; Poudel et al., 2015). This cannot be supported in this study, as cocoa production is affected by many external factors such as weather, economic shocks, supply-side policy variables, etc. (Danso-Abbeam et al., 2020; Djoumessi et al., 2018). Hence, our dependent variable was the bias-corrected PTE_{VRS} scores. Nevertheless, results and discussions on OTE_{CRS} and TE_{NIRS} are also provided.

2.6. Description and justification of variables

Variables of the production function

The dependent variable for the production function is the total output of Cocoa in kilograms (kg). The input variables include land (Ha), Labour force, Depreciation of physical assets, Fertiliser (Kg), density (trees/Ha), Harvest, post-harvest and other expenditures that intervene in the cocoa production process.

Variables of the technical efficiency function

The choice of variables is inspired by literature (Danso-Abbeam et al., 2020; Jebali et al., 2017). The dependent variable is the average technical efficiency of farmers, obtained by a bootstrap procedure. It ranges between 0 and 1. The higher the coefficient, the more efficient the farmer.

The variable of interest is the adoption level of Rainforest/UTZ certification scheme with three modalities: complete, partial and no adoption. Certification can result to improvements in productivity and efficiency. The adoption represents a technology 'package' (training, procedures and techniques) acquisition for farmers to make best use of their inputs and maximise their yields (Suranjan Priyanath et al., 2018). This study contributes to literature as it also accounts for the partial adoption of Rainforest/UTZ cocoa certification scheme.

Human capital comprises education and age of the farmers. A positive sign is expected for schooling. Farmers with high education level are more able to understand and implement farming techniques to become more efficient (Sawadogo et al., 2022). Also, this study makes the assumption that men are as efficient in cocoa production as women. Cocoa production requires a lot of physical strength in the early stages of cultivation, but also requires stamina in the post-harvest phase. The study helps to assess whether the efficiency depends on gender.

The relationship between age and efficiency can be positive or negative. The older farmers can be more productive as they have more experience, better know-how and farming techniques that improve efficiency. Nevertheless, the older farmers can display low efficiency if they are unable to adopt new farming techniques. The young, however, have more incentive to search information and adopt new farming techniques (Coelli and Fleming, 2004).

The years of experience may influence cocoa productivity and farmers' efficiency. The expected relationship is positive. In literature, it contributes to efficiency of production of cocoa farmers (Danso-Abbeam et al., 2020). As farmers obtain more experience, their efficiency improves, as they learn how to reduce supplying costs of inputs, experience economies of scale.

The impact of farm size on technical efficiency is therefore indeterminate. Farmers with less land are more likely to be engaged in off-farm employment, which may negatively affect the time spent on monitoring and appropriately timing sowing, weeding, harvesting and other activities. On the other hand, large farms can have significant costs.

Membership to producers' associations gives room for training sessions, sharing of experiences, and inputs that may boost cocoa productivity. The expected sign is therefore positive. Producers belonging to a farmer's cooperative are expected to have greater efficiency than those out of cooperatives.

This study investigates whether intercropping influences efficiency. From both theoretical and empirical point of view, the effects of intercropping on technical efficiency can be positive (Dlamini et al., 2012; Hong et al., 2019) or negative (Mafoua, 2002; Vedenov et al., 2007). Another contribution of the study is to identify the intercropping pattern (banana, kola, mango and palm oil) which better contributes to cocoa production efficiency.

3. Results

3.1. Descriptive results

In the course of this study, a wide array of data in relation to farmers, farm-specific characteristics, input utilisation and outputs were collected and analysed. The summary statistics for the full sample are presented in table Table 2. The table shows that 94% of cocoa orchard owners surveyed are men with an average age of about 53 years. Also, 57% have attended secondary school or above, 72% are affiliated to producer's organisations, the year of experience of farmers varies between 1 and 54 years with an average of about 26 years.

Table 2: Descriptive statistics of the sample of cocoa farmers (N=100)

	Modalities	Count	Percentage	Mean	Std. Dev.	min	max
Efficiency Model							
Output							
Production (Kg)	Continuous	100		3931.685	4716.197	200	40000
Inputs							
Land (Ha)	Continuous	100		6.356	6.780	1	58
Labour	Continuous	100		307.102	84.4927	1	8375
Depreciation	Continuous	100		79767.123	155822.647	4000	1000000
Fertilizer (Kg)	Continuous	100		147.9867	10.5263	0	1107
Density (trees/Ha)	Continuous	100		1134.73	137.347	400	1300
Harvest expenditure	Continuous	100		181464.21	381426.563	10000	2700000
Post-harvest expenditures	Continuous	100		198688.66	391187.569	3000	3100000
Other expenditures	Continuous	100		62350.033	191076.074	.03	1700000
Farmers' and farm-specific characteristics							
Adoption level	No adoption	33	33.00	1.84	0.692	1	3
	Complete	50	50.00				
	Partial	17	17.00				
Gender	Men	94	94.00	1.06	0.239	1	2
	Women	6	06.00				
Schooling	Primary or less	43	43.00	1.57	0.498	1	2
	Secondary and Higher	57	57.00				
Age	Continuous	100		53.32	11.720	23	84
Age of the farm	Continuous	100		26.02	13.111	1	54
Member of PO's	No	28	28.00	1.72	0.451	1	2
	Yes	72	72.00				
Association with Banana	No	7	07.00	1.93	0.256	1	2
	Yes	93	93.00				
Association with Kola	No	30	30.00	1.7	.461	1	2
	Yes	70	70.00				
Association with Mango	No	75	75.00	1.25	.435	1	2
	Yes	25	25.00				
Association with Palm-oil	No	87	87.00	1.13	.338	1	2
	Yes	13	13.00				

The findings of the study attest to the fact that majority of cocoa farmers practise intercropping with 93%, 70%, 25% and 13% of cocoa farmers who have introduced banana, kola, mango and palm oil trees respectively in their cocoa orchards. Hence, the study shows that cocoa production is a male-dominated activity, in line with Suh et al., (2020) and Suh and Molua, (2022), also majority of farmers have attended formal education unlike the findings of Suh and Molua, (2022). The average age of cocoa farmers estimated at 53 years is slightly above the one found by Iddrisu et al. (2020), this result confirms that the ageing population are most involved in the production of cocoa.

The table shows that the average quantity of cocoa beans harvested is about 3931 kg (3.9 tons). This result is slightly above those found by Suh and Molua (2022) who have shown that cocoa farmers in the South West region of Cameroon had an average cocoa output of 418.98 kg per hectare and a mean output of 1242.9 kg per year. Hence, cocoa farmers in the Centre region might be considered as being more productive than those of the South West region.

The level of adoption of the rainforest Alliance/UTZ certification scheme is also presented in table 1. The results reveal that 33% of cocoa farmers have not adopted cocoa certification meanwhile 50% have completely adopted and 17% have partially adopted the Rainforest alliance/UTZ certification standards. This shows that cocoa certification is gradually gaining ground in the centre region.

As indicated in table 1, the average size cocoa orchard is 6.4 ha with the density of 1134 trees/ha. Cocoa farmers employed about 307 man hours, close to 148 kg of fertilisers in the course of the production campaign. Also, average depreciation charges stand at 79,767 FCFA with harvest, post-harvest and other related expenditure estimated at 181,474 FCFA, 198,688 FCFA and 62,350 FCFA respectively.

3.2. Technical efficiency of Cocoa producers

The distribution of technical efficiency under variable return to scale (VRS), constant return to scale (CRS) and non-increasing return to scale (NIRS) are presented in table 2. The average efficiency score for the surveyed farmers is estimated at 0.926, 0.893 and 0.902 under the assumptions of variable returns to scale (VRS), constant returns to scale (CRS) and non-increasing returns to scale (NIRS) respectively. An analysis of the average efficiency score with respect to the level of adoption reveals that under VRS, the average efficiency score is highest for partial adopters (0.959) followed by complete adopters (0.931) and non-adopters (0.902). Likewise, when considering the CRS scenario, partial adopters have the highest average efficiency score followed by the complete adopters and non-adopters. On the other hand, complete adopters have the highest mean efficiency score followed by the partial adopters and the non-adopters when the NIRS scenario is considered.

Table 3: Efficiency level with respect to the level of participation in certification schemes (N = 100)

	No adoption	**Partial Adoption**	**Complete Adoption**	**Total Sample**
	Number of fully efficient	Number of fully efficient	Number of fully efficient	Number of fully efficient
VRS	9	5	14	28
Percentage	*(32.14)*	*(17.86)*	*(50.00)*	*(100)*
CRS	1	2	6	9
Percentage	*(11.11)*	*(22.22)*	*(66.67)*	*(100)*
NIRS	2	3	7	12
Percentage	*(16.67)*	*(25.00)*	*(58.33)*	*(100)*
Efficiency mean scores				
VRS	0.902	0.959	0.931	0.926
CRS	0.853	0.933	0.905	0.893
NIRS	0.858	0.949	0.950	0.902

As highlighted in literature by (Danso-Abbeam and Baiyegunhi, 2020), a farmer whose technical efficiency score falls below unitary (1) is considered to be relatively inefficient. Building from the above, 28 farmers were efficient at VRS of which 50% (14 farmers) were complete adopters, 17.86% (5 farmers) were partial adopters and 32.14% (09 farmers) were non-adopters. Hence, 72% of the surveyed farmers are inefficient, suggesting that there is a problem of managerial inefficiency for the complete adopters, partial adopters and non-adopters. This result shows that only 28% of farmers have appropriate managerial technic and therefore make good use of their resources. Also, the overall mean efficiency at VRS is 92.6% implying that cocoa farmers are relatively close to the efficiency frontier and could become efficient by addressing their managerial inefficiencies (reducing waste to minimal level and if possible, completely eliminate wastage in resource utilisation).

On the other hand, the number of efficient farmers is lower when CRS was used. Only 9 (9%) farmers were efficient at CRS of which six of them (66.67%) were complete adopters, two are partial adopters and one of them is a non-adopter. The overall mean efficiency score at CRS is 89.3%, showing that farmers are further away from the efficiency frontier when CRS is used relative to VRS. The high rate of inefficiency under CRS may be attributed to inappropriate scale size coupled with poor utilisation of resources. The results corroborate those of (Danso-Abbeam and Baiyegunhi, 2020) whose study notes that more farmers are efficient at VRS relative to CRS.

The results presented in table 2 also show that most farmers are inefficient at NIRS. The number of efficient farmers at non-increasing return to scale is 12, representing 12% of the total sample. Of these farmers, 7 are complete adopters (representing 58.33% of efficient farmers efficient at NIRS), three (3) are partial adopters and two (2) are non-adopters. This result suggests that majority of farmers efficient at NIRS are complete adopters followed by partial adopters. Hence, non-adopters are the most inefficient at NIRS.

Hence, the results presented in table 2 attest to the fact that inefficiency is more common for farmers who have not adopted the Rainforest/UTZ certification standards this verified when considering VRS, CRS and NIRS. However, when comparing partial adopters to non-adopters, partial adopters are more efficient at CRS and NIRS but non-adopters are more efficient at VRS. These findings could be due to the fact that certified farmers undergo training which exposes them to good agricultural practices, thereby causing them to make good use of their resources with minimal waste. On the other hand, non-certified farmers who may have limited knowledge about good agricultural practices are less likely to adopt and maintain good production practices related to land use change.

3.3. The short– and long-run effects of farmers' level of adoption of Rainforest Alliance/UTZ Alliance Certification scheme and technical efficiency

3.3.1. The baseline model

Results from the Truncated model estimations were used to explain variations in farmers' efficiency scores resulting from socioeconomic, farm-specific and institutional factors. The results are presented in two phases: The baseline model (table 4) and the model with interactions (table 5, in annexe). The coefficients with positive signs denote a direct relationship with the efficiency levels, whereas those with negative signs imply they have adverse effects on the farmers' efficiency levels.

The estimated baseline model (table 4) shows that the level of adoption significantly affects cocoa farmers' technical efficiency under assumptions of constant, variable and non-increasing returns to scale. The control group of farmers (non-adoption) has a lower efficiency than the treatment group (complete adoption) under the assumptions of CRS, VRS and NIRS. This result is consistent with the a priori results. As highlighted by Fenger et al. (2017) and Jaza Folefack et al. (2021) complete adopters may be more efficient than non-adopters because certified cocoa producers receive regular training, good follow-up from technical services, advice from their cooperatives and certification bodies and increased access to farm inputs. It also stems from our analysis that, there exists an efficiency gap in favour of partial adopters relative to complete adopters at CRS, VRS and NIRS. However, the efficiency gap reduces in the long-run.

Under the assumption of variable scale performance (VRS), women have a lower average efficiency score than men. Thus, men are more efficient in cocoa production, but this difference is not statistically significant (see table 4). This result can be attributed to women's role in the family, such as cleaning, feeding, raising children, selling agricultural products, which does not leave them enough time for fieldwork. In addition, other reasons may be the unequal allocation of productive resources and limited access to agricultural services such as extension, demonstration farms, and agricultural credit. These findings are in line with several studies (Doss, 2001; Yiadom-Boakye et al., 2013) show that women-managed farms generally have lower productivity than those managed by men. However, other studies (Adeleke et al., 2008; Saito et al., 1994) have shown that women are as efficient as men.

The results presented in table 4 also attest to the fact that the age of the cocoa farmer significantly increases technical efficiency at CRS. The cocoa farmers' technical efficiency increases with the farmers' age and the oldest heads of households are therefore technically more efficient than the youngest. This can be explained by the fact that in the outskirts of Yaoundé, cocoa farming remains the main farming activity of elderly people. Relative to the ageing people, younger farmers are more reluctant to adopt cocoa farming, which remains an activity for the elderly people, retired men and a colonial legacy. Although the youngest cocoa farmers have 23 years of age, these young farmers gradually adopt the new technologies available, generally get trained by the older farmers and collaborate residually with the extension and training agents of the different agencies. Empirical work has found similar results in Lékié – Cameroon (Kamdem, 2018; Tabi et al., 2017), Bako (2016) for Burkina Faso and Nuama (2006) for Côte d'Ivoire.

Farm-specific characteristics such as the size of land under cocoa production and years of experience contribute significantly and positively to the technical efficiency under all assumptions (VRS, CRS and NIRS). These findings agree with the various empirical studies that have argued that land is a critical factor affecting productivity and, subsequently efficiency. Increasing farms size increases costs, but the presence of economies of scope in diversified versus specialised farms tends to lower costs in terms of comparable production levels. Therefore, it increases efficiency. Mafoua (2002) and Baumol et al. (1982) have also shown that strong economies of scope can lead to overall economies of scale that can be greater than one, even though there are constant or decreasing economies of scale per product. This leads to better performances and higher technical efficiency. The results agree with other studies (Danso-Abbeam et al., 2020; Hong et al., 2019; Sawadogo et al., 2022) arguing that size and age of cocoa orchards are positively linked with efficiency.

Membership to producer organisation is a factor that improves the technical efficiency of farmers. Pure technical efficiency of cooperative members exceeds that of non-members by 0.05%. The result goes in line with the a priori expectations of the study. This can be explained by the fact that producers' associations such as farmers' cooperatives are places where information and experiences are shared among producers, and promote the direct acquisition of new skills and best farming good agricultural by members, while non-members have to go through iterative 'trial-and-error' processes that result in low efficiency. Similar results have been found by previous studies (Panpluem et al., 2019; Tabi et al., 2017), which conclude that membership in producer groups improves technical production efficiency.

As presented in table 3, expenditures on training have negative effects on the production efficiency of cocoa farmers assuming CRS and VRS. Hence, producers who spend on training are less efficient than those who do not. This result diverges from the initial hypothesis and can have two explanations. Firstly, producers' incomes are very low and do not allow them to access regular, quality practical training. Secondly, the training programs might not be context specific or would not allow local producers to improve or minimise their production costs by keeping total production unchanged. This result is close to that of Danso-Abbeam et al. (2020b), who argue that demonstration farms provide an opportunity for farmers to learn from the field some of the good farm management practices, which will enhance their technical and managerial skills and subsequently improve their efficiency.

According to the basic model, the association of cocoa with oil palm is the one that significantly improves production efficiency, under all the scale performance hypotheses (VRS, CRS and NIRS). Conversely, the association with mango negatively and significantly affects the efficiency of cocoa production techniques. This may be due to the fact that mango trees have hostile roots and require regular pruning of branches, and in general, bring a lot of rot, which increases costs and reduce the efficiency of cocoa production. The adverse effect of intercropping on technical efficiency is also true for kola, which is significant under the constant return to scale hypothesis (CRS). Intercropping with bananas has no significant effect on technical efficiency. This result is close to that of Jaza Folefack and Darr (2021), for whom agroforestry systems combining fruit cultivation with cocoa benefit the fruit farmers.

Table 4: The effects of farmers' level of adoption scheme on technical efficiency

	Dependent Variables : Technical Efficiency scores					
Variables	VRS	VRS	CRS	CRS	NIRS	NIRS
Adoption (Complete)						
Non adoption	-0.0559**	-0.0106*	-0.0245**	-0.0314*	-0.0331**	-0.0320***
	(0.0221)	(0.0056)	(0.0124)	(0.0167)	(0.0161)	(0.0114)
Partial adoption	0.0745*	0.229***	0.280***	0.0838**	0.102**	0.106***
	(0.0415)	(0.0557)	(0.0675)	(0.0343)	(0.0443)	(0.0359)
Gender (women)	-0.00274	-0.0281	-0.0276	-0.00372	0.0226	0.00132
	(0.0420)	(0.0358)	(0.0435)	(0.0295)	(0.0361)	(0.0284)
Schooling (Secondary or higher)						
Primary or no formal schooling	0.0150	0.0211	0.0299	0.0112	0.0223	0.0133
	(0.0212)	(0.0222)	(0.0270)	(0.0164)	(0.0205)	(0.0167)
Age (in log)	0.0713	-0.0142	-0.0617	0.0741*	0.0341	0.0534
	(0.0598)	(0.0568)	(0.0768)	(0.0417)	(0.0580)	(0.0438)
Age squared	-0.170***	-0.168***	-0.200***	-0.105***	-0.106***	-0.116***
	(0.0456)	(0.0498)	(0.0485)	(0.0321)	(0.0325)	(0.0324)
Experience (in log)	0.0463**	0.0659***	0.0912***	0.0555***	0.0460**	0.0373**
	(0.0240)	(0.0255)	(0.0311)	(0.0189)	(0.0232)	(0.0186)
Experience squared	-0.164**	-0.168	-0.200**	-0.015	-0.116***	-0.186***
	(0.0956)	(0.1498)	(0.0685)	(0.321)	(0.0325)	(0.0324)
Size of the orchards	0.00632**	0.0201***	0.0308***	0.00275**	0.0271***	0.0164***
	(0.00247)	(0.00455)	(0.00602)	(0.00130)	(0.00451)	(0.00326)
Density	-7.10e-05	-0.00018**	-0.00047***	5.00e-05	2.96e-05	1.88e-05
	(7.32e-05)	(7.47e-05)	(0.000133)	(5.21e-05)	(6.41e-05)	(5.39e-05)
Member of PO (yes)	0.0536**	0.0158	0.00707	0.0366**	-0.0143	0.0106
	(0.0244)	(0.0232)	(0.0286)	(0.0171)	(0.0236)	(0.0182)
Transport cooperative (yes)	-0.0537*	-0.180***	-0.191***	-0.116***	-0.0494	-0.114***
	(0.0361)	(0.0428)	(0.0459)	(0.0320)	(0.0372)	(0.0304)
Spending for training (yes)	-0.0462*	-0.0826*	-0.125**	-0.0151	-0.0625	-0.0248
	(0.0248)	(0.0430)	(0.0500)	(0.0298)	(0.0402)	(0.0303)
Intercropping						
Banana (yes)		-0.0103		-0.00420		0.00673
		(0.0407)		(0.0302)		(0.0322)
Kola (yes)		-0.0358		-0.0655***		-0.0268
		(0.0263)		(0.0190)		(0.0206)
Mango (yes)		-0.0524*		-0.0766***		-0.0886***
		(0.0290)		(0.0215)		(0.0221)
Oil palm (yes)		0.0687**		0.124***		0.0982***
		(0.0336)		(0.0260)		(0.0256)
Constant	0.411**	0.887***	1.266***	0.474***	0.529***	0.541***
	(0.200)	(0.183)	(0.293)	(0.140)	(0.189)	(0.144)
Observations	100	100	100	100	100	100
N_bc	1000	1000	1000	1000	1000	1000
ninps	5	5	5	5	5	5
noutps	1	1	1	1	1	1
N_all	100	100	100	100	100	100
sigma	0.0813***	0.0710***	0.0840***	0.0610***	0.0724***	0.0583***
chi2	35.14***	77.89***	69.81***	108.9***	61.55***	125.4***
N_reps	1500	1500	1500	1500	1500	1500
algorithm	Two-step	Two-step	Two-step	Two-step	Two-step	Two-step

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

3.3.2. The interaction model: The role of education, age and experience

The overall results of the baseline and interaction models attest to the fact that certification can gradually enhance farmer's technical efficiency. In this second phase of results, the paper investigates whether some variables cause technical efficiency to change under certain levels of adoption of certification. Equation (2) therefore becomes

$$\hat{\theta}_k = \zeta_o * \text{Adop} + z_k\beta + \alpha\text{Adop x } T_j + \varepsilon_k \quad (3)$$

With A standing for the adoption scheme and T_j, (with j = 1, 2 and 3) representing the transmission channels. The inclusion of interaction terms may arise whenever there are conditional hypotheses. A conditional hypothesis is simply one in which a relationship between two or more variables depends on the value of one or more other variables. Perhaps the simplest conditional hypothesis is:

H1: An increase in any independent variable (Adop) is associated with an increase in dependent variable ($\hat{\theta}_k$) when condition T is met, but not when condition T is absent. The variables considered in this case are age, education level, years of experience in cocoa production can be identified as transmission channels. The transmission channels can be inoperant, or either partially or fully transmit the effects of adoption on technical efficiency (Hair, 2017).

To analyse the significance of the effects, the study mobilises the marginal effects expressed as

$$\frac{\delta Efficiency(\hat{\theta}_k)}{\delta \text{Adop}} = \zeta_0 + \alpha T_i$$

where ζ_o stands for the constant term, T_j (j=1,2,3) refers to the different variables (age, education and experience) interacting with levels of adoption, and α refers to the vector of parameters associated with interacting variables. The statistical significance is reached as soon as whenever the upper and lower bounds of the confidence interval are both above (or below) the zero line (Brambor et al., 2006).

Table 5 presents the results of the model with interactions. This model allows the identification and assessment of the relevant pathways through which the level of adoption of cocoa certification scheme influences the technical performance of cocoa farmers. In other words, the semi-elasticities and partial effects of technical efficiency as a function of certain variables depend on the certification adoption regime (Wooldridge, 2020). Particular emphasis is placed on the variable farmers' age, education attainment and the years of experience in the cocoa orchard. The results in table 5 show that the relationships identified in the baseline model remain constant in general regardless of the assumptions made about returns to scale.

- **Education**

Schooling measured through farmers' education attainment has a positive and significant effect on production technical efficiency (Table 5). Producers with at least secondary education have a technical efficiency that is 6% higher than that of producers with primary or no education. This can be explained by the fact that an educated producer is more likely to grab and get acquainted with modern production techniques and has more chances of obtaining relevant market information (input costs) and could therefore have them at a lower cost. Education is one of the fundamental factors in improving the technical efficiency of cocoa farmers. Several studies conducted in developing countries (Dano-Abbeam et al., 2020b; Djoumessi et al., 2018; Kamdem, 2018; Sawadogo et al., 2022) support this result.

The interaction between education attainment (secondary or higher) and non-adoption as well as partial adoption regimes has a negative effect on technical efficiency relative to producers under the complete adoption regime.

The interaction of education levels and adoption scheme has an overall positive effect on cocoa production efficiency. However, the partial adoption scheme of certification causes underperformance in production efficiency. Individuals at the primary school level and below will have more disadvantages while moving from one regime to another and reduce their production costs in the short term. However, full adoption can improve the efficiency of producers.

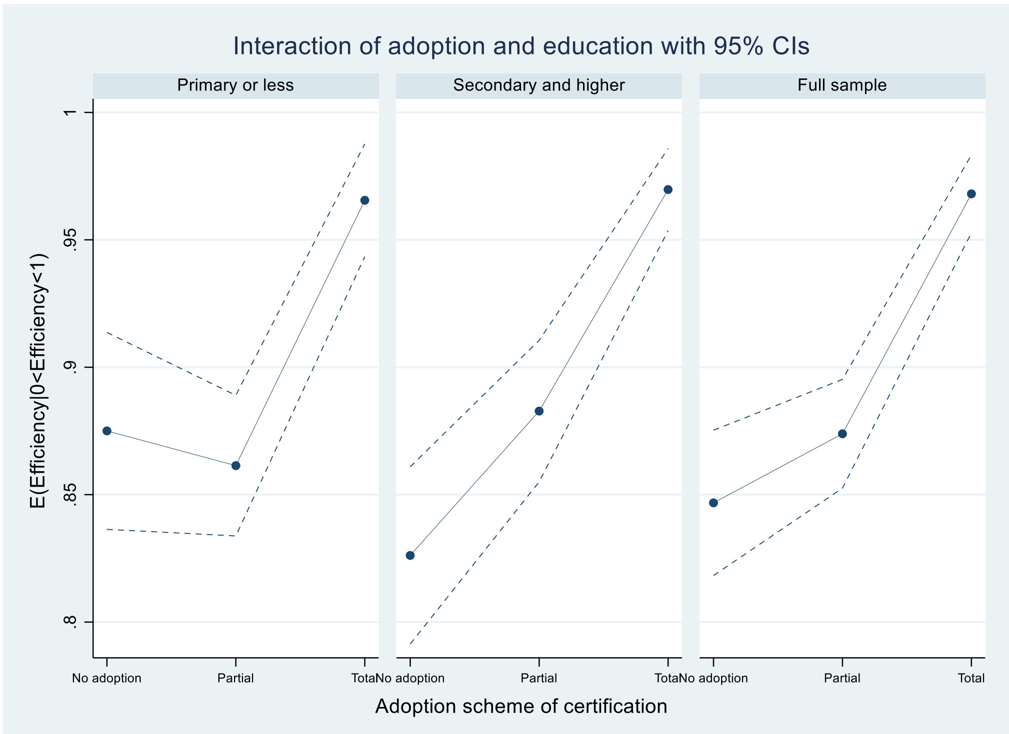

Figure 1: Interactions of education and adoption scheme of certification

Moreover, for the better educated, the transition from partial to full adoption causes better efficiency. This result is intuitive, and shows that producers under the full adoption regime who have a higher level of education are on average better equipped to implement less costly production techniques while maintaining the level of production. Thus, education is a pathway through which adoption of certification schemes boosts farmer's technical efficiency. Hence for education attainment-adoption level interaction, farmers with no formal or primary education level irrespective of whether the non-adopters and adopters, efficiency remains low relative to complete adopters.

- **Age**

The interaction variable farmers' age and level adoption shows that the variable age has a positive effect on efficiency, under all assumptions of returns to scale (VRS, CRS and NIRS). Conversely, for those who do not adopt certification, an additional year has an adverse and significant effect on the technical efficiency of cocoa farmers. However, for producers under the partial adoption scheme, each additional year allows the producer to increase his technical efficiency. Finally, for producers under the complete adoption regime, the interaction effect of the variables has a steeper slope, which reflects a stronger effect. This would allow young cocoa farmers to quickly reach the efficiency levels of older farmers. The complete adoption regime is the one that has the most advantages in minimising costs and improving technical efficiency.

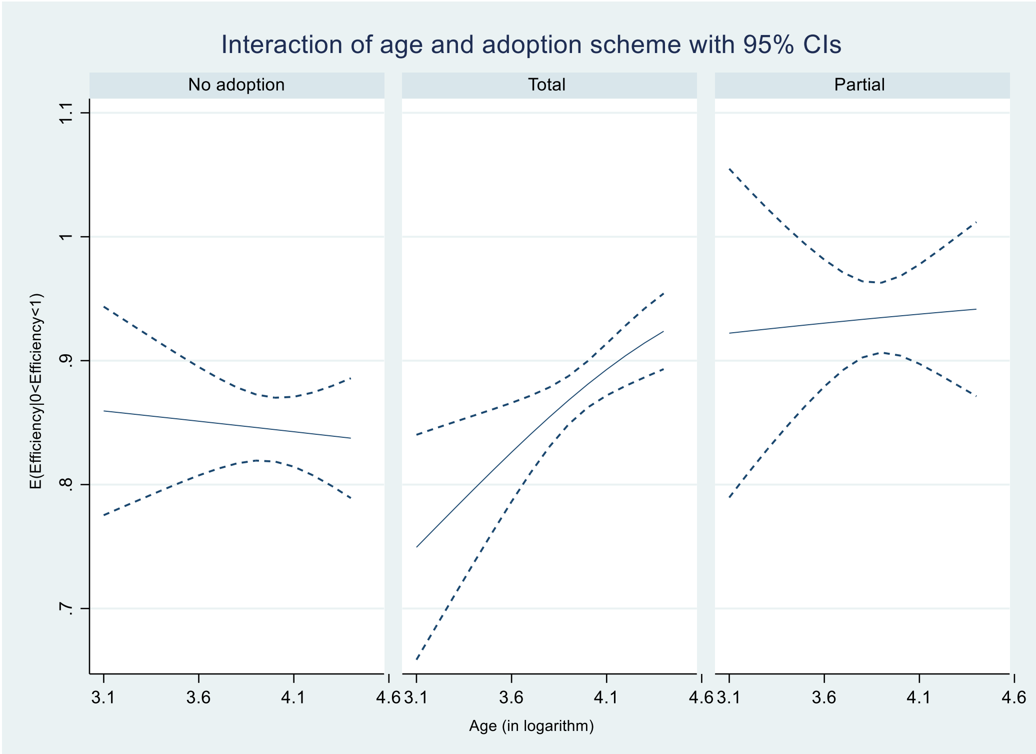

Figure 2: Interactions of age and adoption scheme of certification

- **Experience**

The coefficient of the variable age of the experience variable is positive, indicating that repeating the production process allows the producer to minimise his production costs and increase his efficiency. For producers who have not adopted certification, the interaction coefficient is positive but low at VRS, CRS and NIRS (0.046, 0.0717 and 0.0591 respectively), the experience reduces production costs. However, for producers under the partial adoption scheme, the coefficient is negative and significant under the various scenarios of VRS, CRS and NIRS (-0.296, -0.113 and -0.111). This reflects an interaction effect that is negatively correlated with the technical efficiency of producers. This result can be explained by the difficulty of monitoring two production processes for the same crop, both upstream (preparation) and downstream (post-harvest). Thus, although the producers under this regime obtain high levels of efficiency under this system, they would become inefficient to reduce production costs.

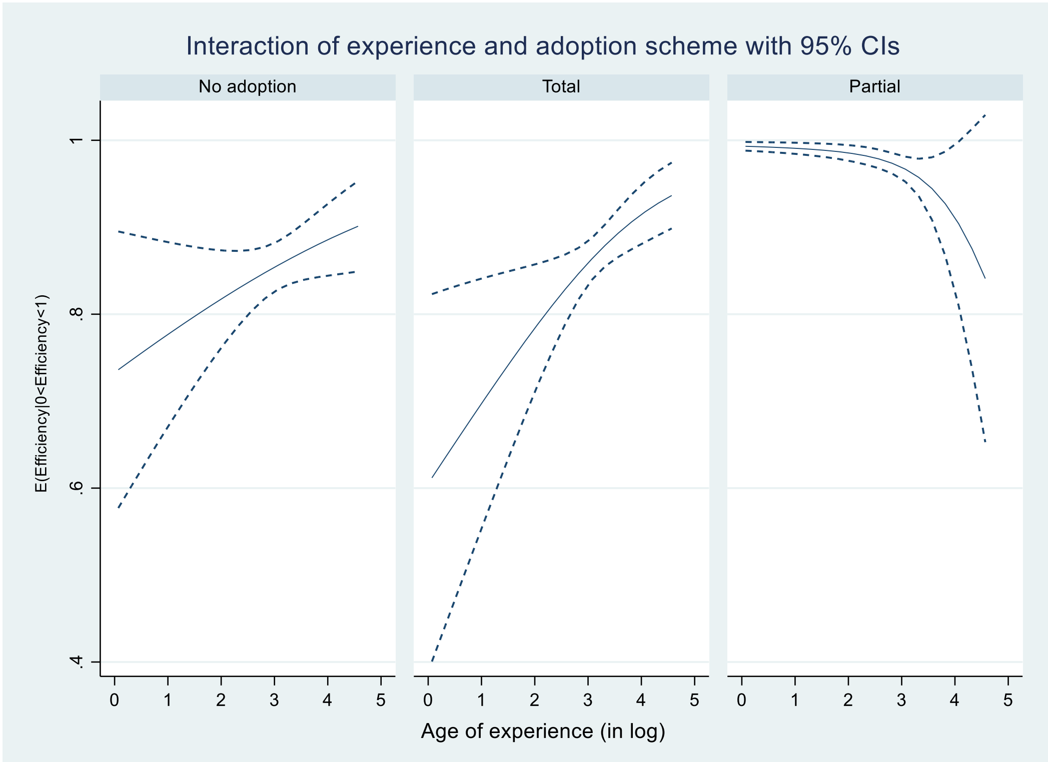

Figure 3: Interactions of experience and adoption scheme of certification

4. Conclusion and Policy Implications

Cocoa certification schemes have gained more recognition over the past years but are still not widespread in Cameroon amongst local cocoa producers. Some farmers have completely ignored certification schemes; meanwhile others prefer to maintain tradition production systems in some orchards alongside the certification system being applied in other orchards and others have completely complied with the certification standards.

Assessing the farm efficiency responses to the level of adoption for cocoa farmers is essential as it can provide an empirical basis to promote the adoption of cocoa certification schemes. This study carried out in the grand Mbam zone of the centre region of Cameroon maintains that cocoa farming remains a male dominated activity. Also, amid the increasing interest of youths in cocoa farming, the activity is still controlled by the elderly people.

The double bootstrapped DEA procedure used to evaluate unbiased farmers' technical efficiency under the assumptions of variable return to scale (VRS), constant return to scale (CRS) and non-increasing return to scale (NIRS) reveals that inefficiency is still rampant amongst cocoa producers with only 28%, 9% and 12% of surveyed farmers experiencing efficiency at VRS, CRS and NIRS respectively. Also, the complete adopters make-up the largest share of efficient farmers under the different assumptions of returns to scale. However, non-adoption of cocoa certification scheme is associated with a high degree of technical inefficiency.

With the double bootstrap estimation procedure, the study presents glaring evidence that adoption of cocoa certification scheme can raise efficiency either partial or complete adoption. In the short run, partial adopters appear to be more efficient than complete adopters but in the long run, this gap gradually declines. This suggests that farmers should gradually abide to the certification standards and extension agents as well as policy-makers pushing for the adoption of certification norms should urge farmers to gradually convert their conventional cocoa plots into certified plots.

The study provides evidence that farmer's age, experience and size of the orchard as well as membership to producers' organisations and association of oil palm trees in cocoa farms are parameters that favour efficiency in cocoa farms in the Mbam zone. Meanwhile increasing plant density, training expenditures, cocoa – mango as well as cocoa – kola associations adversely affect farm efficiency. Also, the interaction non-adoption and age as well as non-adoption and secondary/higher education attainment led to declining efficiency relative to complete adoption. Likewise, partial adopters with no/primary education attainment or experience are less efficient than complete adopters. The study hereby suggests that partial adoption of certification is only viable in the short run and the ideal scenario in the long run is for cocoa producers to attain complete adoption.

The findings of this study provide the basis for policy recommendations. First the study highlights the existence of inefficiency amongst cocoa farmers. In a bid to boost farm efficiency, government extension agents and cocoa certification bodies should organise awareness-raising campaigns through which cocoa farmers shall be informed of how inefficient they are and urged to consciously create conditions favouring efficiency.

Also, certification agencies, conscious of the limited financial resources at the disposal of cocoa farmers should be encouraged these farmers to gradually comply with certification standards by applying the certification norms on their plots progressively while keeping the other plots under the conventional system in the short run. Moreover, policy-makers are urged to encourage cocoa farmers set up and strengthen producers' organisations which serve as avenues for knowledge and know-how exchange.

The intercropping farming system should be adopted by cocoa farmers and cocoa-oil palm association pattern should be the emphasised upon. Moreover, engagement in nonfarm income generating activities should be included in the extension service package because income earned from such activities could help sponsor training expenses, and ease the acquisition of the appropriate quality and quantity of farm inputs recommended by the certification standards.

Author Declarations:

Funding: This research receive no financial support.

Conflict of interest: The author declares no competing interests.

Ethics approval: Not applicable**.**

Consent to participate: All interviewees were consulted prior to their interviews and were anonymised.

Consent for publication: Not applicable.

Availability of data and material/ Data availability: Data is available upon request to the corresponding author.

Code availability: Code is available upon request to the authors.

Authors' contributions: Authors contributed equally for the paper. The final manuscript was read and approved by all authors.

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Annex: Results of the interaction model

Table 5: Model with interactions

	Dependent Variables: Efficiency scores								
Variables	VRS 1	VRS 2	VRS 3	CRS 1	CRS 2	CRS 3	NIRS 1	NIRS 2	NIRS 3
Adoption level (Complete Adoption =ref)									
No adoption	-0.0572**	-0.0920**	0.193	-0.0584**	-0.0692**	-0.226**	-0.0550**	-0.0646**	-0.208**
	(0.0253)	(0.0387)	(0.129)	(0.0275)	(0.0277)	(0.100)	(0.0273)	(0.0273)	(0.0973)
Partial Adoption	0.300***	0.458***	0.244***	0.221***	0.641*	0.484***	0.107**	0.611***	0.481**
	(0.1059)	(0.2058)	(0.0934)	(0.0771)	(0.3887)	(0.182)	(0.0459)	(0.2305)	(0.190)
Gender (women)	-0.0142	-0.0183	-0.0229	-0.00301	-0.00241	-0.00145	0.00883	-0.00834	-0.00651
	(0.0363)	(0.0392)	(0.0373)	(0.0296)	(0.0284)	(0.0289)	(0.0272)	(0.0272)	(0.0279)
Schooling (Secondary or higher)	0.0237	0.0620*	0.0552*	0.0118	0.0365*	0.0374*	0.0131	0.0374*	0.0400*
	(0.0220)	(0.0334)	(0.0318)	(0.0156)	(0.0211)	(0.0225)	(0.0159)	(0.0220)	(0.0220)
Farmer's Age (in log)	0.0601*	0.0578**	0.0457**	0.151***	0.157***	0.0499	0.128**	0.130**	0.0293
	(0.0332)	(0.0223)	(0.0211)	(0.0548)	(0.0550)	(0.0415)	(0.0572)	(0.0558)	(0.0425)
Experience (in log)	0.0729***	0.0704**	0.0950***	0.0318*	0.0301*	0.0773***	0.0225	0.0199	0.0587**
	(0.0251)	(0.0274)	(0.0365)	(0.0184)	(0.0177)	(0.0274)	(0.0191)	(0.0180)	(0.0258)
Size of the orchards	0.0203***	0.0223***	0.0219***	0.00260**	0.00214*	0.00255**	0.0161***	0.0158***	0.0163***
	(0.00443)	(0.00519)	(0.00459)	(0.00124)	(0.00122)	(0.00130)	(0.00316)	(0.00310)	(0.00301)
Density	-0.000231***	-0.000288***	-0.000256***	-6.24e-06	-7.29e-06	9.42e-06	-2.86e-05	-2.87e-05	-1.25e-05
	(7.89e-05)	(8.65e-05)	(8.35e-05)	(5.57e-05)	(5.62e-05)	(5.59e-05)	(5.72e-05)	(5.67e-05)	(5.27e-05)
Member of Producers' Organisation (yes)	0.0154	0.0124	0.0105	0.0356**	0.0253	0.0376**	0.0124	0.000136	0.00640
	(0.0234)	(0.0277)	(0.0280)	(0.0175)	(0.0183)	(0.0187)	(0.0182)	(0.0194)	(0.0202)
Transport cooperative (yes)	-0.170***	-0.168***	-0.200***	-0.105***	-0.106***	-0.116***	-0.103***	-0.0987***	-0.112***
	(0.0456)	(0.0498)	(0.0485)	(0.0321)	(0.0325)	(0.0324)	(0.0327)	(0.0336)	(0.0325)
Spending for training (yes)	-0.0927**	-0.120***	-0.109**	-0.0144	-0.0180	-0.0193	-0.0268	-0.0218	-0.0206
	(0.0424)	(0.0459)	(0.0454)	(0.0278)	(0.0295)	(0.0290)	(0.0309)	(0.0322)	(0.0313)
Interactions									
Adoption and Age									
No adoption#c.agelog	-0.149*	-0.223**		-0.155**	-0.176**		-0.142**	-0.160**	
	(0.0892)	(0.0969)		(0.0693)	(0.0690)		(0.0687)	(0.0682)	
Partial adoption#c.agelog	0.0434**	0.326**		0.0323	0.133*		0.00303	0.126	
	(0.0201)	(0.145)		(0.145)	(0.0784)		(0.147)	(0.150)	
Adoption and education									
Non adoption#Secondary or Higher		-0.106**			-0.0530*			-0.0581*	
		(0.0506)			(0.0308)			(0.0341)	
Partial adoption#Secondary or Higher		-0.0170	-0.107**		-0.0448	-0.0570		-0.0185	-0.0649*
		(0.0799)	(0.0486)		(0.0488)	(0.0348)		(0.0521)	(0.0344)
Adoption and age of the orchard (in log)									
Total adop#co.agexpl									
No adop#c.agexpl			0.0463*			0.0717**			0.0591**
			(0.0279)			(0.0290)			(0.0282)
Partial adop#c.agexpl			-0.296***			-0.113**			-0.111**
			(0.0945)			(0.0508)			(0.0522)
Association									
Banana (yes)	0.00212	0.0571	0.0705	0.00795	0.0234	0.0422	0.0155	0.0326	0.0508
	(0.0408)	(0.0480)	(0.0478)	(0.0311)	(0.0326)	(0.0340)	(0.0320)	(0.0323)	(0.0339)
Kola (yes)	-0.0423	-0.0294	-0.0256	-0.0692***	-0.0640***	-0.0698***	-0.0343*	-0.0251	-0.0263
	(0.0279)	(0.0315)	(0.0311)	(0.0193)	(0.0186)	(0.0199)	(0.0207)	(0.0201)	(0.0210)
Mango (yes)	-0.0362	-0.0236	-0.0455	-0.0638***	-0.0532**	-0.0648***	-0.0732***	-0.0622***	-0.0746***
	(0.0297)	(0.0338)	(0.0309)	(0.0223)	(0.0220)	(0.0220)	(0.0220)	(0.0226)	(0.0217)
Palm oil (yes)	0.0627*	0.0653*	0.0854**	0.111***	0.105***	0.116***	0.0861***	0.0797***	0.0920***
	(0.0331)	(0.0386)	(0.0371)	(0.0260)	(0.0255)	(0.0266)	(0.0264)	(0.0263)	(0.0261)
Constant	0.622**	0.556**	0.918***	0.205	0.163	0.395***	0.278	0.250	0.485***
	(0.252)	(0.280)	(0.211)	(0.192)	(0.190)	(0.142)	(0.194)	(0.191)	(0.147)
Observations	100	100	100	100	100	100	100	100	100
N_bc	1000	1000	1000	1000	1000	1000	1000	1000	1000
ninps	5	5	5	5	5	5	5	5	5
noutps	1	1	1	1	1	1	1	1	1
N_all	100	100	100	100	100	100	100	100	100
sigma	0.0709***	0.0754***	0.0729***	0.0597***	0.0589***	0.0591***	0.0574***	0.0561***	0.0559***
chi2	86.40***	88.58***	92.42***	114.4***	114.3***	113.6***	125.0***	130.7***	128.7***
N_reps	1500	1500	1500	1500	1500	1500	1500	1500	1500
algorithm	Two-step	Two-step	Two-step	Two-step	Two-step	Two-step	Two-step	Two-step	Two-step
N_dea	100	100	100	100	100	100	100	100	100

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1