Asian Journal of Social Science and Management Technology
ISSN: 2313-7410
Volume 4, Issue 3, May-June, 2022
Available at www.ajssmt.com

Adoption of Improved Maize Seeds and Technical Efficiency of Household Farms in NDE Department

Jean Ronald FOTIE NKUETE[1], Martini Rodrigue MBOCK[2], Hervé BertrandYAKAN[3], Pierre FEUJIO TEGUEFOUET[4]

[1, 3]*(Faculty of Economics / University of Maroua, Institute of Agricultural Research for Development,Cameroon)*
[2]*(Faculty of Economics / University of Yaoundé II, Institute of Agricultural Research for Development,Cameroon)*
[4]*(Institute of Agricultural Research for Development, Cameroon)*

ABSTRACT: This study examines the effects on technical efficiency of adopting improved maize seeds on 80maize farms in Ndé department of western Cameroon. Using the stochastic production frontier model of sample selection, selection bias from observable and unobservable farmer characteristics was taken into account because farmers self-select to adopt improved maize technologies. The results indicate that adopters are more technically efficient than non-adopters. Furthermore, adoption of improved maize seeds is associated with increased productivity of maize farms, compared to non-adoption. Furthermore, the results show significant inefficiencies in production and thus a large scope for improving farmers' technical efficiency through better use of the resources available at the current level of technology.

Keywords - Adoption, Improved maize seed, Propensity Score Matching, Stochastic frontier Production,Technical Efficiency.

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1. INTRODUCTION

The appearance of innovations on the market creates opportunities to improve efficiency; but this improvementdoes not take place immediately because new technologies are characterized by imperfect information. Indeed,there is a market imperfection linked to the lack of information on the conditions of use, risks and performanceof the latter. In this case, the number of adopters increases as information becomes available (Foster and Rosenzweig, 1995; Bandiera and Rasul, 2006). The producer's decision thus depends on the maximisation of an expected utility (or profit) under certain constraints such as the availability of land, credit, etc. (Feder et al., 1985). (Feder et al., 1985). In Cameroon, despite the increase in maize production mainly due to the increase in cultivated area, maize is still insufficient to meet the increased demand (FAO, 2016). This low productivity can be explained, among other things, by the decline in soil fertility, the use of inappropriate cultivars (seeds, cuttings, etc.). In addition, farmers mainly use traditional seeds.

Nevertheless, drought is perceived by farmers in many agro-ecological zones as a disruptive factor in crop production including maize (Manu et al., 2015). The adverse effects of drought due to global warming therefore continue to reduce production in the different agro-ecological zones of the country, due to the lack of wide adoption of varieties tolerant to this abiotic factor. To remedy this situation, the Institute of Agricultural Research for Development (IRAD) and the International Institute of Tropical Agriculture (IITA) have initiated research projects on drought-tolerant maize such as: CMS 8501, CMS 8704, variety Kasai (CHC 201), variety ATP (CHC 202), variety CHC 203, variety Coca, variety CHH 101, variety CHH 108, variety SHABA and variety PANA. These varieties have potential average yields of 7 tons/ha, thus hypothetically highlighting a productivity gap between users of improved seeds and non-users. The objective of this study is therefore to demonstrate the impact of the adoption of improved maize seeds on technical efficiency of household farms in Ndé department in western Cameroon.

2. REVIEW OF THE LITERATURE

One of the first authors to analyze the adoption of agricultural technologies from an economic perspective was Griliches (1957). Using data on US farmers, he estimated a logistic function to identify the determinants of the adoption of hybrid maize varieties. He showed that both supply and demand are important factors, but also the profitability of new varieties. However, methodological constraints such as considering adoption as a continuous variable when it is discrete, as well as the omission of some factors, make these conclusions questionable. In their study on the adoption of improved groundnut varieties in Uganda Kassie et al. (2011) found that membership of a farmer organization, farm size and education level increased the probability of adopting improved groundnut varieties. Solomon et al (2014) looked at the adoption of improved wheat varieties in Ethiopia. Their results indicate that education level, market access, diversity of information sources, agro- ecological zone, price of the harvested product as well as distance to seed sellers are determinants of adoption.Khonje et al (2015) studied the adoption of improved maize seeds in Zambia. In their work, access to extensionservices, levels of education, access to credit and association membership are the determinants of adoption of improved maize seeds.

In sum, in most of the studies, the impacts of the adoption factors are in the same direction except for the age and size of the farm, for which the signs may vary from one study to another. This finding suggests that the studycontext may play an important role in the analysis of adoption factors. From this perspective, understanding thephenomena of acceptance and rejection of an innovation means placing it in its societal context, by carrying out a complete analysis of the local society. Thus, this study will legitimize or not the dissemination of improved maize seeds throughout Cameroon.

3. METHODOLOGY AND DATA

3.1. ADOPTION OF IMPROVED MAIZE SEEDS

The main objective of this study is to examine the effects of the adoption of improved maize seeds on the technical efficiency of family farms. The binary decision of a farm to adopt or not to adopt improved maize seeds can be modelled in a random utility framework (Imbens, 2000; Hirano and Imbens, 2001). In our context, we assume that a farm is risk-neutral, and that it makes an adoption decision based on the comparison between the expected benefits of adopting and not adopting improved maize seeds. Ideally, a farm will choose to adopt improved maize seeds if the expected benefit of adoption (D_A) is greater than the expected benefit of non-adoption (D_N), i.e. $D_i^* = D_A - D_N \succ 0$, where represents D_i^* the difference between the expected benefits of adopting and not adopting improved maize seeds. Furthermore, D_i^* is a latent variable, which is unobservable, but can be expressed as a criterion function of observable characteristics as follows:

$$D_i^* = \delta' Z_i + \mu_i \text{ with } D_i = \begin{cases} 1\_if\_D_i^* \succ 0 \\ 0\_if\_D_i^* \leq 0 \end{cases} \quad (1)$$

Where D_i is a binary adoption indicator, which is assigned a value of 1 if the farmer i decides to adopt improved maize seeds and 0 otherwise. In this study, we define an adopter as a farm that planted at least one improved maize variety in the 2020 crop year; δ is a vector of parameters to be estimated; denotes Z_i a vector of observable factors influencing a farm's adoption decision; is μ the error term, with zero mean and variance ($\sigma^2 = 1$ $\mu_i \sim N[0,1]$). The probability of a farm adopting an improved maize variety is represented by the following specification:

$$\Pr(D_i = 1) = \Pr(D_i^* \succ 0) = \Pr(\mu_i \succ -\delta' Z_i) = 1 - F(-\delta' Z_i) \quad (2)$$

Where F is the cumulative distribution function of μ_i. Intuitively, the adoption of improved maize technologies by family farms can increase their technical efficiency.

3.2. STOCHASTIC PRODUCTION FRONTIER MODEL (SPF)

Using the stochastic production frontier (SPF) model in the empirical estimates, we assume that farms either adopt or do not adopt the improved maize seeds. The SPF model is specified as follows:

$$Y_{ij} = f\left(X, D_i\right) + v_{ij} - u_{ij} \quad (3)$$

Where denotes Y_{ij} the output of the i^{eme} farmer, X represents a vector of inputs and other factors, is D_i a dichotomous variable capturing the effect of adoption of improved maize seeds, v_{ij} and u_{ij} are respectively, the two-sided error term, and the one-sided error term that captures efficiency. Note that the index j represents D_A for adopters of improved maize seeds, and D_N for non-adopters. In non-experimental studies, as in this case, estimating the impact of adoption of improved maize seeds on productivity and technical efficiency requires addressing the farmer selection bias arising from the non-random assignment of adoption and non-adoption of improved maize seeds to ensure unbiased and consistent estimates of the impact of adoption. The following section presents the results of our study and discussion of these results.

3.3. DATA COLLECTION AND STUDY AREA

This study uses data from a survey conducted by the Institute of Agricultural Research for Development (IRAD) on production systems and farm efficiency of maize farms in the Ndé department (West Cameroon Region). Data were collected in four districts (Bangangté, Tonga, Bazou and Bassamba districts) during the period from 31 August 2020 to 20 November 2020, using a multi-stage sampling procedure. In the first stage, we used purposive sampling to select the four study districts because of their geographical accessibility, intensive maizeproduction in these districts and proximity to the IRAD Bangangté Multipurpose Agricultural Research Station (SPRA). This was done by consulting the maize seed sales files of the Bangangté SPRA and the files of donations made to displaced persons during the security crisis in the North-West and to war veterans and victims of war in the Ndé department. The second step was a random sampling of two to three communities in each arrondissement studied. Finally, a total sample of 80 maize farmers, comprising 46 adopters and 34 non- adopters, was drawn for analysis as a proportion of the maize farmer population in each district. These farmers were interviewed using a structured questionnaire, and information on farm characteristics, asset ownership, and production, consumption and marketing activities related to the 2020 production season was collected by research assistants, under the supervision of the authors.

4. RESULTS AND DISCUSSION

4.1. DESCRIPTIVE STATISTICS

The definition and summary statistics of the variables used in the analysis are presented in Table 1. As can be observed, 57.5% of the sampled farmers are adopters of improved maize seed in the study area. In addition, the average age of the head of the farm, the average experience of the farm in maize cultivation, the average length of occupation of the farm plot and the average length of fallowing of the plot are 39 years, 5 years, 4 years and 15 months respectively. On average, a farm cultivates 6312.5 m2 of maize plot and generates an average harvest of 305.64 kg. In addition, a farm uses an average of 10.25 kg of maize seed with an average labor force of about 4 people.

Table 1: Definition of variables and descriptive statistics

Variable	Definition	Mean	Std. Dev.
Seeds_type2 (improved)	1 if the farm uses improved seed and 0 otherwise	.575	.497
Quantity harvested	Quantity of maize harvested (in Kg)	305.637	370.744
Quantity of seed	Quantity of maize seed used (in Kg)	10.25	8.792
Parcel area	Surface area of the exploited plot (in m2)	6312.5	4516.282
Number of individuals	Number of individuals working on the plot	3.95	1.799
Age	Age of the head of the holding (in years)	39.212	7.142
year experience	Farm experience in maize cultivation (in years)	5.362	2.512
Cat_sociopro1 (Own account)	1 if the holder is self-employed and 0 otherwise	.212	.412
Cat_sociopro2 (Employer)	1 if the holder has a job as an employer and 0 otherwise	.163	.371
Cat_sociopro3 (Employee)	1 if the manager has a job as an employee and 0 otherwise	.138	.347
Cat_sociopro4 (Middle management)	1 if the holder has a job as a middle manager and 0 otherwise	.325	.471
practical training1	1 if the head of the holding has already received training in agriculture and 0 otherwise	.75	.436
gender2 (Male)	1 if the manager is male and 0 otherwise	.65	.48
op coop member1	1 if the holding is a member of a PO or cooperative and 0 otherwise	.725	.449
credict access1	1 if the holding has access to credit and 0 otherwise	.563	.499
loc_operator1 (Bangangté)	1 if the farm is located in the Bangangté district and 0 otherwise	.475	.503
loc_operator2 (Tonga)	1 if the holding is located in the district of Tonga and 0 otherwise	.163	.371
loc_operator3 (Bazou)	1 if the holding is located in the district of Bazou and 0 otherwise	.175	.382
number year occupied	Duration of occupation of the agricultural parcel(s) (in years)	4.551	3.771
operating assistance	1 if the holding receives agricultural technical assistance and 0 otherwise	.4	.493
institutional support	1 if the farm has institutional support and 0 otherwise	.287	.455
plot burning	1 if the farm practices burning on its plot(s) and 0 otherwise	.313	.466
number of months fallow	Duration of fallowing of the agricultural plot(s) (in months)	15.264	10.661

Source: Based on survey data.

4.2. PROPENSITY SCORE MATCHING ANALYSIS

Table 2 shows significant differences between adopters and non-adopters of improved maize seed. Firstly, the proportion of members of farmers' organizations or cooperatives differs between the groups: 84.8% of adopters are members of farmers' organizations or cooperatives, compared to 55.9% of non-adopters. With regard to gender, 73.9% of adopters are male, compared to 52.9% of non-adopters. For the socio-professional category3 (employee), 4.3% of adopters belong to this category against 26.5%. Also, adopters are on average older than non-adopters (41 years old compared to 36 years old). These significant differences in the means of the explanatory variables are assumed to be the basis for self-selection into adoption.

Table 2: Test of differences in means before matching

Variable	Mean		%bias	p>t
	Treated	Control		
age	41.522	36.088	84.200	0.001
corn_experience_year	5.739	4.853	35.700	0.119
Cat_sociopro1 (Own account)	0.196	0.235	-9.500	0.673
Cat_sociopro3 (Employee)	0.043	0.265	-63.500	0.004
practice_training1	0.783	0.706	17.400	0.440
gender2 (Male)	0.739	0.529	44.000	0.053
op_coop_member1	0.848	0.559	65.800	0.004
credict_access1	0.609	0.5	21.700	0.339
loc_operator1 (Bangangté)	0.478	0.471	1.5	0.947
loc_operator3 (Bazou)	0.217	0.118	26.600	0.251

Source: Based on survey data.

After matching, there were no significant differences between the means of the explanatory variables. This means that the treated and untreated groups are comparable in terms of observable variables.

Table 3: Test for differences in means after matching

Variable	Mean		%bias	p>t
	Treated	Control		
age	38.853	37.500	21.000	0.368
corn_experience_year	5.176	4.324	34.300	0.791
Cat_sociopro1 (Own account)	0.265	0.294	-7.100	0.791
Cat_sociopro3 (Employee)	0.059	0.059	0	1.000
practice_training1	0.706	0.735	-6.700	0.791
gender2 (Male)	0.647	0.412	49.400	0.751
op_coop_member1	0.794	0.853	-13.400	0.532
credict_access1	0.559	0.647	-17.600	0.465
loc_operator1 (Bangangté)	0.529	0.794	-52.300	0.621
loc_operator3 (Bazou)	0.147	0.088	15.700	0.459

Source: Based on survey data.

In sum, the results of the balancing test indicate that the unmatched sample does not satisfy the balancing property as there are significant differences between the means of socio-professional category3 of the head of the farm, gender, age and membership of a farmer organization or cooperative before matching (Table 2). However, the results after matching indicated that there was no statistical difference in the observed characteristics between adopters of improved maize seed and non-adopters (Table 3). Based on this result, it was concluded that the comparison was statistically valid (Rosenbaum and Rubin, 1983).

Fig. 1 presents a graph of treated and untreated units after matching through the common carrier condition, which is a criterion to be checked for matching quality. The first remark on the distribution of propensity scores among maize farms is the fact that it is quite disparate (non-concentration around 0), reflecting a fairly good adoption rate of improved maize seed. The common support is equally satisfactory with an average overlap of probabilities for treated and untreated.

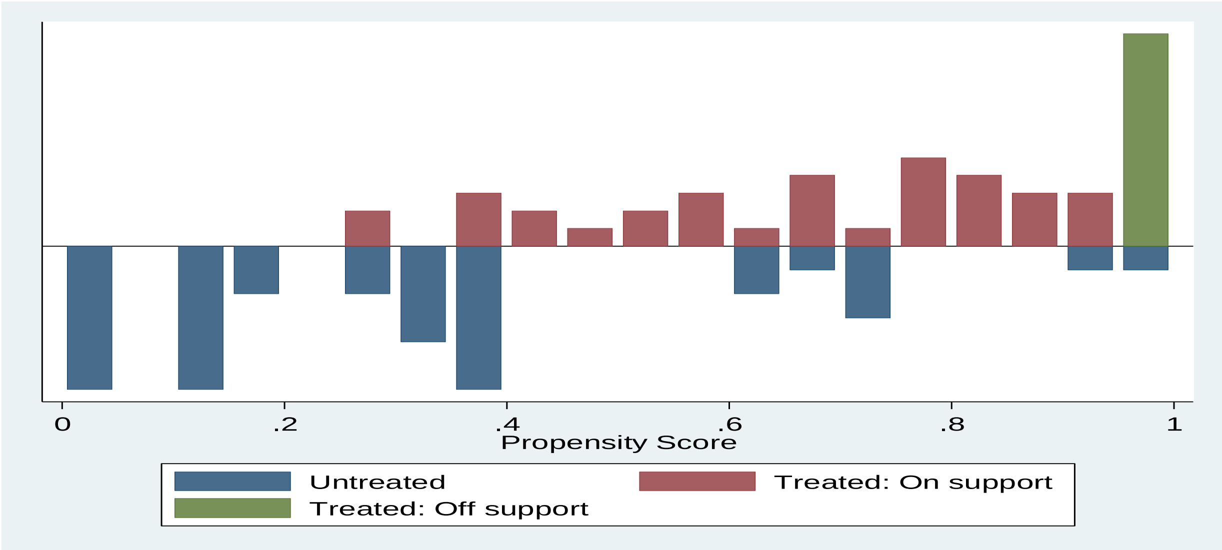

Figure 1: Distribution of propensity scores and common support
Source: Based on survey data.

A Probit model was used to estimate the conditional probability of adopting improved maize seed given observed farm characteristics, where the dependent variable equals one if the farm has adopted improved maize seed and zero otherwise. We calculated marginal effects to allow us to better interpret the results (Greene, 2012). A summary of the results of the Probit model is presented in Table 4. The model has good validity as indicated by the pseudo-R2 (0.216) and the chi-square probability value (0.000). In addition, six of the ten variables included in the model have a significant effet on the adoption of improved maize seed. Farm managerslocated in Bangangté have a 26.8% higher probability of adopting improved maize seed as indicated by the positive and significant marginal effect of the variable loc_exploitant1. Farms that are members of farmers' organizations or cooperatives are 68.1% more likely to adopt improved maize seed, while farms headed by older individuals with years of experience in maize cultivation are 3.79% and 7.67% more likely to adopt improved maize seed respectively. This result is similar to that of Adesina and Zinnah (1993) obtained in Sierra Leone and that of Asfaw, Shiferaw, Simtowe, and Haile (2011) obtained in Ethiopia. However, we can find that being employed or self-employed reduces the probability of adopting improved maize seed by 58.8% and 46.7% respectively. These results are quite similar to previous studies conducted by Khonje et al. (2015) in Uganda andNabasirye et al. (2012) in Zambia on the impacts of adoption of improved maize seeds on maize yields and welfare.

Table 4: Factors influencing the decision to adopt improved maize seed

	(1)	(2)
VARIABLES	**Probit coefficients**	**Marginal effects**
Age	0.101**	0.0379**
	(0.0433)	(0.0155)
corn_experience_year	0.205**	0.0767**
	(0.0894)	(0.0326)
Cat_sociopro1	-1.654***	-0.588***
	(0.538)	(0.147)
Cat_sociopro3	-1.254**	-0.467**
	(0.616)	(0.192)
practice_training1	-0.176	-0.0649
	(0.471)	(0.170)
gender2	-0.442	-0.160
	(0.477)	(0.165)
op_coop_member1	2.000***	0.681***
	(0.571)	(0.134)
credict_access1	0.00935	0.00350
	(0.378)	(0.142)
loc_operator1	0.735*	0.268*
	(0.422)	(0.148)

loc_operator3	0.760	0.249
	(0.625)	(0.166)
Constant	-5.710***	
	(1.945)	
Comments	80	80

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

Source: Based on survey data.

As suggested by Caliendo and Kopeinig (2008), Table 5 presents other criteria for assessing the quality of matching, namely the maximum likelihood test, the pseudo-R2 and the mean bias.

Table 5: Quality indicators before and after matching

Sample	Ps R2	LR Chi2	p>Chi2	Average bias
Unmatched	0.357	38.980	0.000	37.000
Matched	0.148	13.910	0.177	21.700

Source: Based on survey data.

The results indicate a fairly good quality of matching. Indeed, the pseudo-R2 is quite low after matching (1.48%). In addition, the maximum likelihood tests are rejected before matching but not after. The average bias is also quite low compared to the unmatched sample.

4.3. ESTIMATING IMPACT OF ADOPTION OF IMPROVED MAIZE SEEDS ON TECHNICALEFFICIENCY

We present in Table 6 the maximum likelihood estimates of the parameters of the Cobb-Douglas stochastic frontier model based on the propensity score matching subsample. Two of the three inputs in our study have a positive impact on technical efficiency. The significant positive effect of these variables confirms the monotonicity condition that marginal products are positive at the average levels of these inputs. However, the labor factor has a negative impact on technical efficiency. This can be explained by the fact that the labor force on these farms is exclusively family-based and made up of young children, which seems to slow down the adults during field work. The results of the estimation of the stochastic frontier model show that a 1% increase in the quantity of seeds used increases production by 0.78%, while a 1% increase in the area of land increases production by 1.52%. In addition, a 1% increase in labor reduced production by 1.36%.

Table 6: Estimation of the parameters of the stochastic model

	(1)	**(2)**	**(3)**
VARIABLES	**LnProd**	**lnsig2v**	**lnsig2u**
LnSeed	0.781***		
	(0.217)		
LnLabour	-1.360***		
	(0.404)		
LnLand	1.522***		
	(0.255)		
Constant	-6.876***	-1.951***	0.698***
	(1.982)	(0.475)	(0.240)
Comments	68	68	68

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

Source: Based on survey data.

Table 7 presents the results of the average treatment effect on treated individuals (ATT) using different matching methods. The standard errors of the impact estimates were calculated by bootstrapping using 100 replications for each estimate. The results revealed that the adoption of improved maize seed had a significant positive impact on technical efficiency. For all matching methods, a positive impact was achieved at the 1% significance level. For the Nearest Neighbor, Kernel and Radius methods, farm households that adopted improved maize seed recorded increases of 24.4%, 23.8% and 27.9% respectively in their technical efficiency on average compared to control farm households. These results are consistent with other previous studies in Uganda and Zambia on the impacts of adopting improved maize seeds on maize yields and welfare (Khonje et al., 2015; Nabasirye et al., 2012).

Table 7: ATT Estimates of impact of improved seeds on Technical Efficiency

Matching Algorithm	Coefficient (ATT)	Bootstrap Std. Error
Nearest Neighbor	0.244**	0.057
Kernel	0.238**	0.051
Radius	0.279**	0.053

*** p<0.01, ** p<0.05, * p<0.1

Source: Based on survey data.

4.4. TECHNICAL INEFFICIENCY MODEL

The parameters of the technical inefficiency function were estimated using the censored Tobit estimation procedure. A summary of the results is presented in Table 8. The coefficients of the input variables represent the elasticity. The inefficiency model suggests that farm household inefficiency is significantly associated with the proportion of farms receiving assistance, the proportion of farms that are members of farmers' organizations or cooperatives, the socio-professional category of the head of the farm, and the proportion of farms that are members of a cooperative, the proportion of farms benefiting from institutional support, the locality in which the farm is located, the proportion of farms adopting improved maize seed, the number of months the plots are left fallow and the number of years the farm has been growing maize. Access to improved seed has a positive and significant impact of 0.26 units on the technical efficiency of maize farms.

Table 8: Estimation of the inefficiency model

VARIABLES	(1) Model	(2) Sigma
number_of_occupancy_year	-0.00280	
	(0.00688)	
operating_assistance	-0.123***	
	(0.0418)	
op_coop_member	0.198***	
	(0.0546)	
Cat_sociopro	0.0395*	
	(0.0214)	
institional_support	0.105**	
	(0.0434)	
practice_training	-0.0461	
	(0.0581)	
burn_on_plot	0.0743	
	(0.0447)	
credict_access	-0.0122	
	(0.0309)	
loc_operator	0.0327**	
	(0.0129)	
adoption_seed_am	0.258***	
	(0.0326)	
number_months_jachhre	-0.00897**	
	(0.00335)	
year_experience_but	-0.0335***	

	(0.00946)	
Constant	0.494***	0.0917***
	(0.0811)	(0.00987)
Comments	46	46

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

Source: Based on survey data.

The results confirm the findings of Shaheen, Sial, Sarwar and Munir (2011) and Onumah et al. (2010) who suggest that the adoption of new technologies is likely to make farms technically more efficient. Efficiency gains throughadoption of improved maize seed confirm the findings of Karimov (2014). In Ghana, Asante et al, (2014) found a 3.1% increase in technical efficiency for adopters of NERICA rice varieties. Abate et al (2013) also found that participation in farmer cooperatives increases technical efficiency by 5.6% in Ethiopia. Chaovanapoonphol, et al.(2009) also found a similar result where access to technical assistance was found to significantly increase the technical efficiency of rice farmers in the Upper North of Thailand.

5. CONCLUSION

The study examined the effet of improved seed adoption on the technical efficiency of maize farms in the NDE department located in western Cameroon using cross-sectional data from 80 farms. The study involved the estimation of a model of improved maize seed adoption and a Cobb-Douglas production function. We controlledfor self-selection using propensity score matching and found that technical efficiency varied significantly on average between farms adopting improved maize seed and those not adopting it. Controlling for self-selection using the Propensity Score Matching approach to match farms based on their observed characteristics allowed us to obtain a more reliable comparison of technical efficiency for adopters and non-adopters. The significant positive effect of improved maize seed adoption on farm technical efficiency provides ample evidence of the crucial role of agricultural research in creating improved climate-tolerant varieties such as the ATP variety (CHC202) used in the West Cameroon region. The inefficiency model confirms these results by showing that the adoption of improved maize seed increases the technical efficiency of maize farms. The results of this study also suggest that policies to improve the technical efficiency of maize farms should encourage them to form farmer organizations or cooperatives, while benefiting from technical assistance in monitoring their plots and from institutional support. Once these conditions are met, access to improved seeds could significantly boost their technical efficiency.

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Corresponding Author: ***Jean Ronald FOTIE NKUETE, Faculty of Economics / University of Maroua, Institute of Agricultural Research for Development, Cameroon.***

How to cite this article: ***Jean Ronald FOTIE NKUETE, Martini Rodrigue MBOCK, Hervé Bertrand YAKAN, Pierre FEUJIO TEGUEFOUET, Adoption of Improved Maize Seeds and Technical Efficiency of Household Farms in NDE Department, Asian. Jour. Social. Scie. Mgmt. Tech.2022; 4(3): 197-207.***