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EFFECT OF ADOPTION OF ICT ON TECHNICAL EFFICIENCY OF FARMS IN BURKINA FASO

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ABSTRACT

This study aimed to explore the effet of Information and Communication Technology (ICT) adoption on the technical efficiency of farms in Burkina Faso. Data were collected from 420 farmers in the central region, selected through simple random sampling across 47 villages. Descriptive statistics were computed, and a Stochastic Frontier Production model was applied to estimate farm technical efficiency. The estimation results indicate that, overall, input and labour costs are lower among ICT users (UTIC), compared to non-users (NUTIC) for similar agricultural outputs. Furthermore, the results reveal a significant difference in technical efficiency scores (0.049) between UTIC (0.338) and NUTIC (0.289), suggesting that ICT adoption positively influences farm technical efficiency. These findings highlight the need to promote ICT adoption among farmers, as their use reduces input and labour costs; while enhancing overall efficiency. Public policies should facilitate access to ICT in rural areas to support agricultural productivity and sustainability.

Key Words: Adoption, Burkina Faso, ICT, technical efficiency

RÉSUMÉ

Cette étude avait pour objectif d'explorer l'effet de l'adoption des technologies de l'information et de la communication (TIC) sur l'efficacité technique des exploitations agricoles au Burkina Faso. Les données ont été collectées auprès de 420 agriculteurs de la région centrale, sélectionnés par échantillonnage aléatoire simple dans 47 villages. Des statistiques descriptives ont été calculées et un modèle Stochastique de Frontière de Production a été appliqué pour estimer l'efficacité technique des exploitations agricoles. Les résultats des estimations indiquent que globalement, les coûts d'intrants agricoles et de main d'œuvre sont relativement faibles chez les utilisateurs de TIC (UTIC) par rapport aux non-utilisateurs de TIC (NUTIC) pour les mêmes résultats. Par ailleurs les résultats indiquent également un écart significatif de scores d'efficacité technique (0,049) entre les UTIC (0.338) et les

NUTIC (0.289) suggérant que l'adoption des TIC a un effet positif sur l'efficacité technique des exploitations agricoles. Ces résultats impliquent de promouvoir l'adoption des TIC parmi les agriculteurs, car leur utilisation réduit les coûts d'intrants et de main-d'œuvre tout en améliorant l'efficacité technique des exploitations agricoles. Des politiques publiques devraient faciliter l'accès aux TIC dans les zones rurales.

Mots Clés : Adoption, Burkina Faso, TIC, efficacité technique

INTRODUCTION

In sub-Sahara African (SSA) countries, the under performance of the agricultural sector is attributed to, in part by various factors, including the inefficient allocation of available resources in the production process (Sawadogo *et al.*, 2022). In these contexts, where the pressure to boost agricultural productivity is steadily rising, adoption of information and communication technologies (ICTs) is increasingly regarded as potential strategies for the technical efficiency of agricultural operations (Aker, 2011; Spielman *et al.*, 2021).

In the SSA countries, agricultural enterprises face growing challenges, including low adoption of modern practices; thus justifying the need for innovative solutions to improve technical efficiency (Diagana, 2024). Empirical studies indicate that the under performance of agricultural enterprises often results from a lack of relevant information and technological knowledge among farmers (Okello *et al.*, 2012; Ogutu *et al.*, 2013). ICTs emerge as promising strategic tools for optimising agricultural practices, enhancing decision-making, and integrating farmers into innovation networks.

In this context, several authors demonstrate that ICTs are effective tools for informing and training farmers on best agricultural practices; and for promoting informed choices towards adopting sustainable agricultural practices (Spielman *et al.*, 2021; Kang *et al.*, 2023). However, Spielman *et al.* (2021) argued that the direct effects of ICTs on technical efficiency may not be immediately perceptible, suggesting that the use of ICTs by farmers in farm management does not necessarily lead to improved technical efficiency.

In Burkina Faso in particular, low agricultural yields have persisted over the years (MARAH, 2024); despite the increasing integration of ICTs into the daily lives of Burkinabe farmers (INSD, 2022). The agricultural sector exhibits one of the lowest average annual growth rates in total factor productivity (TFP) in Africa, with a significant portion of this growth attributed to low technical efficiency (Combary and Savadogo, 2014). Nevertheless, Chloé and Bationo (2019) demonstrated that in Burkina Faso, ICTs provide remote support to farmers by facilitating the sharing of agricultural information and knowledge to improve technical efficiency, among other things. The objective of this study was to explore the effects of adopting information and communication technologies (ICTs) on the technical efficiency of agricultural, enterprises in the Central region of Burkina Faso.

Theoretical framework. This study was grounded in Theodore W. Schultz's (1961) theory, which provides a relevant conceptual framework for examining the mechanisms through which ICT adoption influences the technical efficiency of agricultural enterprises.

The human capital theory, developed by Theodore W. Schultz in 1961, posits that investment in education, training and health is essential for enhancing productivity and economic development. Schultz (1961) emphasises that the skills and knowledge acquired by individuals, play a crucial role in economic growth. According to this theory, education and training improve workers' abilities to increase their efficiency and potential income. This theory will illuminate not, only the direct impacts of these technologies on the technical efficiency of agricultural enterprises, but also the indirect effects related to the enhancement of farmers' skills, decision-making and institutional integration.

MATERIALS AND METHODS

Study area. The study was conducted in the central region of Burkina Faso, located between longitude 2°00' and 1°15' West; and latitude 12°45' and 12°00' North. The central region comprises of a single province, subdivided into an urban municipality with special status, encompassing of five districts and six rural municipalities. These six rural municipalities consist of 187 villages.

The primary economic activities in the rural communes of the central region of Burkina Faso include agriculture and crafts. In 2023, maize ranked first in production in Burkina Faso, followed by red sorghum, white sorghum and rice (MARAH, 2024). Over the past five agricultural seasons, the average cereal yields have been declining (MARAH, 2024).

The central region of Burkina Faso is characterised by a higher use of ICTs compared to other regions (INSD, 2022). The most popular ICTs in the rural communes include landline and mobile phones, FM radios and televisions, along with various applications, and the internet.

Data collection. Initially, an exploratory survey was conducted using a semi-structured questionnaire, administered to 20 farmers in the research area, to pretest the instrument. This step allowed for adjustments to the questionnaire and the rephrase of certain questions for precision to improve the quality of the responses.

The main survey was carried out on a total of 420 farmers randomly selected from 47 villages in the research area. The 20 respondents interviewed during the questionnaire pre-test were excluded from the final sample used for the main survey.

Data analysis. This study focused on five primary ICTs used in the central region of Burkina Faso; namely (i) mobile phones (Tm), (ii) the Internet (Int), (iii) mobile money transfer technology (TArgM), (iv) radio (Radio), and (v) television (Tv) (INSD, 2022).

Empirical model. The empirical framework of this study aimed to use econometric methods to explore the effect of adopting ITC on the technical efficiency of agricultural farms. Based on literature, two primary methods are commonly used to measure technical efficiency; namely (i) Data Envelopment Analysis (DEA), a non-parametric approach; and (ii) the Stochastic Frontier Analysis (SFA), a parametric approach. Each method has specific characteristics with its own advantages and limitations (Zheng *et al.*, 2021; Kang *et al.*, 2023).

The DEA method considers multiple outputs and assumes constant returns to scale; and interprets any deviation from the frontier as inefficiency (Charnes *et al.*, 1978). However, it has a notable limitation for agricultural research, where inputs affect production over multiple years. This method also focuses on a single period of analysis and does not account for the cumulative effects of inputs across several agricultural seasons (Coelli *et al.*, 2005).

In contrast, the SFA method incorporates random factors and distinguishes between the impacts of random phenomena on the production process and technical inefficiencies (Aigner *et al.*, 1977). According to Meeusen and van den Broeck (1977), although this method relies on pre-established assumptions regarding the distribution of variables and parameters, it allows for statistical analysis and hypothesis testing due to the properties of the production function used. However, Coelli *et al*. (2005) pointed out that SFA is based on rigid assumptions concerning the functional form of the production, and the distribution of inefficiency terms. These limitations can be problematic in the agricultural sector, given the complexity and heterogeneous nature of agricultural practices, which may not be fully captured by the SFA. Battese and Coelli (1995) have developed an SFA method incorporating random factors to distinguish technical inefficiencies from fluctuations attributable to external factors. In particular, this approach makes it possible to take into account the impact of climatic conditions and measurement errors, which are frequent in the agricultural sector.

In addition to accounting for random factors, the present study employs the Stochastic Frontier Analysis (SFA) method, developed by Battese and Coelli (1995) to analyse the effects of ICT adoption on the technical efficiency of agricultural farms for several reasons. First, the Battese and Coelli (1995) model allows for the inclusion of explanatory variables in the technical inefficiency component to explain differences in levels of technical efficiency. Second, unlike other models, SFA assesses efficiency at the individual farm levels, enabling a specific evaluation of how ICT adoption improves or limits the performance of different farms. Finally, the Battese and Coelli (1995) model is robust as it utilises a specified production function (e.g. Cobb-Douglas, Translog), allowing the exploration of nonlinear interactions between inputs (including ICT) and outputs, providing a detailed view of the direct and indirect effects of ICT on agricultural production.

Variable selection. The choice of variables included in the analysis was based on those identified in the empirical literature (Yaseen *et al*., 2016; Diendere, 2019; Ebele *et al*., 2019). The data collected made it possible to classify farmers into two groups; namely (i) ICT users (UTIC) and (ii) ICT non-users (NUTIC). The outcome variable selected is the value of agricultural production (Prod), which represents income from the sale of agricultural products by farmers surveyed. The input variables refers to the factors used in production. The variable "SuperEmb" represents the area cultivated by the farmer; while "Sem", "FO", "NPK", "Urea", "Pest" and "MO" represent the total costs of seed, organic fertiliser, NPK fertiliser, urea fertiliser, pesticides and labour, respectively, expressed in United States dollars. The other control variables are sex (Sex), age (Age), education level (Inst), household size (TailM), distance between the household and the municipal market (DistM) ; membership of a producer organisation (ApOP), regular contact with an extension agent (PEAPC), farm income (RevA), number of active farm workers in the household (Acta), non-farm income greater than (RevNA) and frequency of supervision (FrEnc).

Empirical model specification. The Stochastic Frontier Analysis (SFA) model (Battese and Coelli, 1995) used was based on a normal distribution, to estimate the technical efficiency of ICT users and non-users. This model aims at analysing the technical efficiency (TE) of agricultural farms, by estimating the Stochastic Production Frontier and measuring deviations from this frontier (Battese and Coelli, 1995). The model follows the Cobb-Douglas functional form, expressed as follows:

$$lnYi = \beta 0 + \sum_{j=1}^{n} \beta j lnXij + vi - ui$$

………………………………… Equation 1

$$Ln(Y) = \beta0 + \beta1\, Ln(X1) + \beta2\, Ln(X2) + \beta3\, Ln(X3) + \beta4\, Ln(X4) + \beta5\, Ln(X5) + \beta6\, Ln(X6) + \beta7\, Ln(X7) + vi - ui \quad \text{………… Equation 2}$$

Where :

Y = Value of agricultural production (US$);
$X1$ = Area sown by the farmer (ha);
$X2$ = Total cost of seed;
$X3$ = Total cost of organic fertiliser;
$X4$ = Total cost of NPK;
$X5$ = Total cost of urea;
$X6$ = Total cost of pesticides; and
$X7$ = Total cost of labour
vi = Symmetrical error term, representing random factors (exogenous, statistical noise); and
ui = Technical inefficiency term ($ui \geq 0$).

After estimating Equation 2, we calculated the technical efficiency (TE) scores between the ICT user and non-ICT user groups. We then compared the technical efficiency scores between the two groups. The technical efficiency score for farms was calculated using Equation 3.

$$TE = \frac{Yi}{Y*i} = e^{-u} \quad \text{………… Equation 3}$$

Where :

TE = TE score of agricultural production on the farm ;
Yi = observed production level;
$Y*$ = "optimal" production level in the context where all inputs employed (Xi) have been used in the most efficient way; and e^{-u} = exponential function of the negative inefficiency term ($-ui$).

Equation 3 shows that ICT users, by achieving higher agricultural output (Yi) for the same level of inputs (Xi), can achieve a higher technical efficiency (TE) score than non-users.

RESULTS

Descriptive statistics. Table 1 presents the descriptive statistics of the variables used in the empirical analysis. Overall, the findings indicate that approximately 57% of the sampled farmers utilise information and communication technologies (ICTs) in their agricultural production; while 43% do not, suggesting a relatively widespread adoption of ICTs within the study area.

The results further reveal that the total value of agricultural production is significantly higher among ICT users (UTICs) ($843.16) compared to non-ICT users (NUTICs) ($815.02), with a statistically significant difference of $28.14 (Table 1). This suggests that ICT adoption may enhance the technical efficiency of farms by improving resource allocation and input management.

Regarding input utilisation, UTICs cultivate a slightly smaller sown area than NUTICs (1.35 ha vs. 1.48 ha), which may indicate more efficient land management among ICT users. Additionally, UTICs incur lower costs for seeds, organic fertilisers, and pesticides. However, the cost of NPK is significantly lower for UTICs ($154.18) compared to NUTICs ($264.57), suggesting a more efficient approach to fertiliser use among ICT-adopting farmers.

Furthermore, labour expenses are lower among UTICs ($122.54) relative to NUTICs ($136.53), which may reflect improved labour management or the adoption of more efficient farming practices (Table 1). These findings suggest that UTICs optimise resource utilisation more effectively, leading to increased production and reduced input costs. This

TABLE 1. Descriptive statistics and definitions of empirical variables used in the study on the effects of ICT adoption on the technical efficiency of farms

Variables	Description	Mean			
		All	UTIC	NUTIC	Diff
UTIC	The farmer uses ICT in agricultural productio		0,57(0,50)	0,43(0,50)	
Result variable					
Production	Production total value of agricultural production (US$)	960,04 (105,46)	843,16 (66,47)	815,02 (16,69)	28,14*
Input variables					
SuperEmb	Area sown by farmer (ha)	1,49(1,22)	1,35(0,78)	1,48 (1,24)	-0,02
Sem	Total cost of seed (US$)	70,43(12,23)	56,77 (11,04)	79,75 (12,92)	-22,98
FO	Total cost of organic fertiliser (US$)	123,88 (12,20)	120,88 (12,33)	127,87 (12,04)	-6,16
NPK	Total cost of NPK (US$)	241,26 (39,3)	154,18 (11,30)	264,57 (42,05)	-110,39**
Urea	Total cost of urea (US$)	74,59 (8,64)	64,77 (6,01)	79,92 (9,21)	-15,15
Pest	Total cost of pesticides (US$)	17,32 (3,57)	16,32 (3,37)	18,65 (3,82)	-2,33
MO	Total cost of labour (US$)	135,86 (20,24)	122,54 (18,89)	136,53 (16,68)	-13,99
Control variables					
Sex	Sex of farmer (1= male, 0= female)	0,62(0,48)	0,76(0,42)	0,43(0,49)	0,33
Acta	Number of farm workers in household	5,64(3,34)	5,65(2,95)	5,64(3,81)	0,01
Age	Age of farmer (year)	44,83(12,14)	44,36(11,75)	45,45(12,64)	-1,09
Inst	Farmer's level of education (1= educated, 0= uneducated)	0,51(0,5)	0,64(0,47)	0,34(0,47)	0,3
TailM	The number of people in the farmer's household (Number)	9,37(5,1)	9,27(4,56)	9,49(5,75)	-0,22
DistM	Farmer is more than 5 Km from his village to the commune's main market (1=yes, 0=no)	0,67(0,46)	0,61(0,48)	0,74(0,43)	-0,13
ApOP	Farmer is a member of a producer organisation (1=yes, 0=no)	0,42(0,49)	0,46(0,49)	0,37(0,48)	0,09
FrEnc	Frequency of farmer supervision	2,85(3)	3,43(3,48)	2,09(2,01)	1,34
PEAPC	Farmer is in contact with an advisory support agent (1=yes, 0=no)	0,77(0,42)	0,85(0,35)	0,65(0,47)	0,2
RevNA	Farmer has a non-agricultural income of over 200 thousand (1=yes, 0=no)	0,34(0,47)	0,41(0,49)	0,25(0,43)	0,16
RevA	Farmer has an agricultural income of over 200 thousand (1=yes, 0=no)	0,34(0,47)	0,41(0,49)	0,25(0,43)	0,16

Standard deviation is shown in paranthes; *, ** and *** indicate the mean difference (t-test) between the ICT users (UTIC) and non-users (NUTIC) groups at the 10, 5 and 1% levels of significance, respectively. Source: From survey data (2024) supports the premise that ICT adoption contributes to enhanced technical efficiency in agricultural production.

Finally, with respect to the control variables, the results indicate a higher proportion of male farmers among UTICs (76%) compared to NUTICs (43%) (Table 1). Additionally, the level of education is significantly higher among UTICs (64%) than among NUTICs (34%). These findings suggest that gender and educational attainment positively influence farmers' ability to adopt and effectively utilise ICTs in agricultural activities (Table 1).

Input and labour management and optimisation of agricultural resources. The estimated results reveal significant differences in input elasticities between ICT users (UTICs) and non-users (NUTICs). For example, the elasticity of seed use (ln_Sem) was considerably higher for UTICs (0.0807) than for NUTICs (0.0231) (Table 2). This suggests that UTICs derive greater benefits from their seed investments, indicating more efficient management of this input.

On the other hand, the elasticity of NPK was significantly higher for NUTICs (0.1646) compared to UTICs (0.0205) (Table 2). This finding suggests that NUTICs rely more heavily on NPK to enhance their production, whereas ICT users may be optimising their fertiliser use through improved information access.

The results also indicate that ICT adoption contributes to better input cost management. This is evidenced by the negative coefficient for organic fertiliser use among UTICs (-0.00 45), in contrast to the positive coefficient observed among NUTICs (0.0165) (Table 2). This suggests that access to ICTs enhances resource optimisation, which in turn may improve the technical efficiency of farms.

Regarding labour expenditure (ln_MO), the estimated coefficient is significantly higher for UTICs (0.0515) than for NUTICs (0.0326). This implies that ICT users utilise labour more efficiently, potentially due to improved farm

TABLE 2. Estimation of the stochastic production frontier model of the study on the effects of ICT adoption on the technical efficiency of farms

Variables	ICT user (UTIC)	Non-users of ICT (NUTIC)
ln_SuperEmb	0,3048***(2,18)	0,2961*(1,69)
ln_Sem	0,0807***(5,00)	0,0231**(2,46)
ln_FO	-0,0045(-0,23)	0,0165(1,70)
ln_NPK	0,0205(0,76)	0,1646***(15,76)
ln_Urée	0,0414*(1,85)	0,0058***(2,12)
ln_Pest	0,0315(1,49)	0,0037(0,27)
ln_MO	0,0515***(3,28)	0,0326***(3,74)
$\sigma^2 v$	12,5872***(50,68)	11,7559***(340000)
$\sigma^2 u$	0,0579(0.30)	1,3066***(12,46)
	-0.973***(-5,31)	-33,461(-0,16)
Wald (Chi2)	103,25	276,38
Prob > chi2	0,0000	0,0000
Log-vraisemblance	-399.88	-250.99
N	238	182

Asterisks indicate significance at the 10 percent (*), 5 percent (**) and 1 percent (***) levels. Figures in brackets correspond to standard errors. Source: From survey data (2024)

TABLE 3. Technical efficiency (TE) scores from the study on the effects of ICT adoption on the technical efficiency of farms

Designation	ICT users (UTIC)	Non-ICT users (NUTIC)	Difference
TE-SPF	0,338 (0,205)	0,289(0,224)	0,049
Observations	238	182	

Source: From survey data (2024)

management practices facilitated by ICT adoption.

Overall effect of ICT on farm technical efficiency. Regarding the average technical efficiency (TE) scores estimated from the stochastic frontier models for ICT users (UTICs) and non-users (NUTICs), the results indicate that the mean TE score is 0.338 for UTICs and 0.290 for NUTICs (Table 3). The observed TE difference of 0.049 between the two groups suggests that ICT adoption is associated with enhanced technical efficiency. This implies that farms utilising ICT are better able to optimise their production processes compared to those that do not, likely due to improved access to information and better resource management.

DISCUSSION

The analysis of results underscores the significant impact of ICT adoption on the technical efficiency of farms. The marked differences between ICT users (UTIC) and non-users (NUTIC) provide deeper insights into how technology influences input management and farm yield optimisation.

Input management, labour efficiency, and resource optimisation. The estimation of the stochastic frontier model reveals that UTICs utilise seeds more efficiently than NUTICs, as indicated by the elasticity of seed use (0.0807 for UTICs versus 0.0231 for NUTICs). This finding aligns with previous studies by Zheng *et al*. (2021) and Kang *et al*. (2023), which demonstrated that farmers with access to ICT benefit from better information on cultivations techniques and improved seed selection. The increased efficiency in seed utilisation may stem from precise recommendations provided by ICT tools on optimal farming practices.

Conversely, NUTICs exhibit a greater reliance on chemical fertilisers, particularly NPK, whose elasticity is significantly higher (0.1646 for NUTICs versus 0.0205 for UTICs). This suggests that ICT access enables more strategic fertiliser use, likely due to improved planning based on crop-specific nutrient requirements. This trend corroborates the findings of Mwalupaso *et al*. (2019), who reported that access to agricultural information via ICT enhances input optimisation among farmers.

Moreover, ICT adoption appears to positively influence labour utilisation on farms. The elasticity of labour costs is higher for UTICs (0.0515) than for NUTICs (0.0326), suggesting that ICT adoption facilitates better labour productivity through improved management and supervision of agricultural activities. These results are consistent with Obayelu *et al.* (2023), who found that ICT access enhances work organisation and task allocation, reducing inefficiencies in labour management.

Additionally, the negative elasticity for organic fertiliser costs among UTICs (-0.0045) compared to the positive elasticity for NUTICs (0.0165) suggests improved management of natural resources. This may be attributed to access to information on agroecological practices and optimised use of organic amendments. This observation aligns with Ndiaye (2018), who found that farms integrating ICT into their agricultural practices demonstrated superior efficiency in fertiliser and input utilisation.

Overall impact on farm technical efficiency. The difference in technical efficiency (TE) scores between UTICs (0.338) and NUTICs (0.289) highlights the overall positive impact of ICT adoption on farm efficiency. The 0.049-point increase in TE can be attributed to enhanced resource management, greater adaptability to changing agricultural conditions, and improved decision-making. This finding is in line with research by Ben Farah and Amara (2023) and Mwikamba *et al*. (2024), who demonstrated that ICT adoption enhances farm productivity and efficiency.

One of the key findings of this study is that ICT adoption significantly enhances the technical efficiency of farms by improving input management, reducing reliance on chemical fertilisers, and optimising labour costs. This result aligns with a broader body of empirical evidence that consistently reports positive efficiency gains associated with ICT integration in agriculture. However, this study also highlights that socio-demographic factors, particularly education level and gender, play a crucial role in the adoption of ICT. These findings are consistent with Schultz's (1961) human capital theory, which posits that investments in education, skills development, and training enhance farmers' technical efficiency by strengthening their human capital.

This study confirms that ICT adoption significantly contributes to improving the technical efficiency of farms by optimising input utilisation, increasing labour productivity, and enhancing overall resource management

CONCLUSION

The primary objective of this research was to examine the impact of ICT adoption on the technical efficiency of farms in the Centre region of Burkina Faso. The findings reveal that ICT users (UTIC) exhibit superior input management, particularly in seed utilisation; while simultaneously reducing their reliance on chemical fertilisers through improved planning and resource allocation. Furthermore, ICT adoption enhances labour productivity, facilitating more efficient workforce management and the optimisation of agricultural resources.

The results also demonstrate that the overall influence of ICT on farm efficiency is reflected in the higher technical efficiency scores observed among ICT users compared to non-users. Consequently, this study confirms the research hypothesis that ICT adoption contributes to improving the technical efficiency of farms.

These findings have several key implications; from a policy perspective, they highlight the necessity of expanding ICT access in rural areas and fostering its adoption through targeted interventions. In terms of agricultural development, this research contributes to the existing literature by providing empirical evidence of the pivotal role of ICT in enhancing farm efficiency. Additionally, from a research standpoint, the study opens new avenues for investigating the broader relationship between digital technologies and agricultural performance, particularly in terms of agricultural productivity and farm economic profitability.

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