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Welfare impact of organic cotton adoption in Benin

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Abstract

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Abstract

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1. Introduction

For decades, conventional cotton has been a driving force in the transformation of agricultural production systems and a structural aspect of local economies in sub-Saharan African countries. However, the sustainability of conventional cotton-based production systems is often questioned because of their effects on soils and the negative impacts of chemical control on the environment and human health. Land degradation due to the intensive use of chemicals and fertilizers leads to the increasingly declines in farm income, increased poverty and degradation of producers' well-being due to the harmful effects on health and costs associated to it (Keikha et al., 2023; Thorat & More, 2022). From this perspective, several empirical works have favoured organic cotton as not only contributing to the reduction of poverty but also building resilience among agricultural producers (Parvez et al; 2018; and Shepherd; 2019). Similarly, several studies have considered the excessive use of fertilizers and chemicals as source of progressive decline in soil fertility which corollary effects are recurrent declines in farm income, degradation of welfare, and health of conventional cotton farmers (World Bank 2013; Sodjinou et al, 2015; Krause and Machek, 2018).

Indeed, conventional cotton production counts for more than 75% of agricultural growth in Benin and holds 85% of employment in rural areas (INSAE, 2021). This sector provides income to more than half of its 8 million citizens (MAEP, 2021). Despite Benin's position in cotton production, which is largely contributed by the northern region of the country in 2019, this region had an incidence of monetary poverty of 42.1 for Alibori, 60.5 for Atacora, and 53.3 for Borgou. These alarming and surprising incidences of poverty suggest that conventional cotton does not concretely improve the well-being of producers and the ones of their community

Theoretically, the adoption of agricultural technologies is the result of rational behaviour. In fact, the farmer chooses between different chemical, organic, biological, and mechanical innovations to improve his/her well-being (Menard, 1990). Janvry et al. (2016) demonstrated three channels through which agricultural technologies improve farmers' welfare, notably improving their productivity, income, and consumption. In addition, agricultural technologies are knowledge- and management-intensive, indicating large generation of externalities beyond the targeted crop. The Walrasso-Paretian model made three successive breaks: the first consists in introducing a hypothesis of imperfect information on the part of the agents; the second concerns the form of the rationality of individual behaviour, whether substantive or procedural; finally, the third one concerns the object of the organizational coordination of individual behaviour: the management of transactions or the implementation of cognitive processes.

Empirically, the adoption of conventional and organic cotton has generated many controversies regarding the environmental risk, economic and financial profitability, and human health issue. Thus, Krause and Machek (2018) confirmed that the economic profitability of organic cotton is better than the conventional one. They concluded that the yields of this type of cotton are progressively increasing and improving farm incomes and producers' welfare while reducing rural poverty. In the same vein, the work by Náglová and Vlasicova (2016) showed that the majority of conventional farms have healthy financial indicators such as returns on assets, equity, and production costs. These farms showed the highest growth rate of profitability (+79%) for return on assets. They concluded that organic farming is truly environmentally friendship and generates farm income that can improve the welfare of adopters. Deka and Goswami (2021), using primary data from smallholder farmers, evaluated the economic potentialities of small-scale organic crop. Their results revealed that per hectare annual income from organic crops was significantly greater than that from conventional, i.e. non-organic crops, reducing rural poverty among organic crop adopters. In contrast, Agalati et al (2020) revealed that the adoption of organic cotton was associated with higher transaction costs that hurt the adoption and lowered its economic performance

Despite the scope of these studies, a limited number simultaneously examined the drivers and welfare impacts of organic cotton adoption with rigorous impact evaluation methods. Our article contributes to extending this strand of the existing literature. The objectives of this paper are twofold. First, we investigate the drivers of the adoption of organic cotton production in Benin. Second, we analyse the impacts of organic cotton adoption on farmers' welfare.

Based on the existing literature, we assume that (i) the adoption of organic cotton is driven by institutional factors and (ii) organic cotton decreases poverty among adopters. Indeed, if farmers fully adopt organic cotton, this will increase the cotton yield. Then, under perfect market conditions, the cotton income of adopters will increase, which in return will lead to a significant reduction of poverty among adopters. The rest of the paper is organized as follows: the first section presents the theoretical and empirical theories, while the second addresses the methodology focusing on data and estimation methods. The third section presents the results and discussion. The last one concludes and gives some policy implications.

2. Methodology

2.1.Data

This study uses data from a secondary database obtained from the Sustainability of Cotton Production in Africa Project (SCOPA) in Benin. These data come from a survey of cotton producers in the Borgou, Atacora, and Alibori districts, between June and July 2019. The survey included a sample of 1416 producers randomly selected through a two-stage sampling approach. These regions were chosen because of their highly contribution (80%) to Benin cotton production on the one hand, and have better weather conditions that fit more with food crops cultivation such as maize, millet, and yams on the other hand. From total of 1416 producers surveyed, 331 produce organic cotton, corresponding to an adoption rate of 23.38%. The questionnaire included a set of information on the socio-demographic and economic characteristics of the producers, access to agricultural loan, crops produced, and yield.

2.2. Well-being measurement

Several indicators are used for measuring well-being in the economic literature, notably income, consumption expenditures, inequality, and environmental quality. Generally, consumption expenditures are the most widely used in microeconomic studies. However, Benin "Sustainability of Cotton Production in Africa" (SCOPA) survey does not provide information on cotton producers' consumption. As so, annual net income of producers expressed in CFA francs and poverty through its two indicators, notably the poverty incidence and the poverty gap are used. The Foster-Greer-Thorbecke (FGT) approach was used to measure the poverty level as follows:

$$P_\alpha = \frac{1}{N}\sum_{i=1}^{q}\left(\frac{Z - Y_i}{Z}\right)^\alpha \quad (1)$$

Here P_α is the poverty indicator, Y_i is the net annual income of producer , α refers to the poverty parameter, which denotes either incidence or gap and takes the values 0 and 1, respectively; N is the size of the sample expressed as the number of households, and q is the proportion of the population below the poverty limit which is Z. This poverty limit was measured by the rural poverty threshold reported in Benin's Harmonized Survey on Living Conditions of Households (EHCVM) conducted in 2019. According to this study conducted in the eight West African Economic Monetary Union (WAEMU)[1] countries, the overall annual poverty threshold is estimated at 246,542 FCFA (US $441.50). This threshold is composed of a food component of 146,793 FCFA (US $262.84) and a non-food component of 99,749 FCFA (US $178.66).

2.3. Model

As a reminder, the objective of this paper is to analyse the impact of the adoption of organic cotton on the welfare of farmers in Benin. In particular, it assesses the difference in income and poverty levels between organic cotton producers and those who produce only conventional cotton. Within this framework, our methodological approach consists of three steps. First of all, we examine the determinants of producers' adoption of organic cotton. Next, we estimate the determinants of the allocation of organic cotton acreage to be grown by producers once the decision to adopt organic cotton has been made. Finally, we estimate the impact of organic cotton production on producers' welfare.

2.3.1. Sequential adoption model

Our adoption model is based on the expected utility theory of Neumann & Morgenstern (1945), for whom the producer adopts organic cotton if only the expected utility of the adoption is higher than the utility gained from the conventional cotton producer. Formally, we have:

$$U\left(X, \mathrm{Z} \mid \mathrm{y}=1\right) \succ U\left(X, \mathrm{Z} \mid \mathrm{y}=0\right) \quad (2)$$

Thus, we adopt a sequential adoption model of organic cotton that involves two choices, namely a discrete choice and a continuous choice. The adoption of such a model was justified by the fact that cotton producers can decide to produce either only organic cotton, only conventional cotton, or the both types simultaneously. Thus, the first level of producer's decision is a discrete choice about whether or not to adopt organic cotton. The second level of decision is a continuous choice

[1] The WAEMU members are Benin, Burkina, Guinea Bissau, Côte d'Ivoire, Mali, Niger, Senegal, and Togo.

when the producer must decide on the intensity of organic cotton production following the adoption decision. In other words, the producer must decide how much surface to allocate to organic cotton production. This decision process can be analysed as follows:

$$U_i^* = F\left(X, \varepsilon\right) \text{ with } U_i = \begin{cases} 1 \text{ if } U_i^* \succ 0 \\ 0 \text{ otherwise} \end{cases} \quad (3)$$

In this model, U_i^* denotes a latent variable measuring the difference between the utility of adopting organic cotton U_{iA} and the utility of the status quo U_{iN}, i.e. not adopting organic cotton by farmer i. Thus, the producer adopts organic cotton if $U_{iA} \succ U_{iN}$. The variable X is a vector of characteristics that affect the producer's decision, and ε is the error term. To take into account the sequential process of the producer's decision in the estimation of the adoption model, we use the two-step approach of Cragg (1971). In the first step, we estimate the probability of adoption of organic cotton through Probit regression. In the second step, we apply a truncated regression to estimate the intensity of adoption. Indeed, it is obvious that not all producers have adopted organic cotton production. Thus, this leads to the censoring of the organic cotton area variable through the presence of several zeros for non-adopting producers. Such a situation is well-modelled in corner solution models where the optimal solution for some producers is non-adoption (Wooldridge et al., 2010). Thus, the organic cotton area is formalized as follows:

$$AOC_i = Max\left(0, \text{AOC}_i^*\right) \quad (4)$$

Where AOC_i^* is a latent variable that denotes the linear specification of organic cotton acreage and is defined as follows:

$$AOC_i^* = \eta_0 + \eta_1 X_i + \eta_2 T_i + \eta_3 I_i + \varepsilon_i \quad (5)$$

In equation 5, X is a vector of socio-demographic variables of the producer (age, gender, education level, residence, number of years of experience), T is a vector of technical characteristics of the producer (quantity of seed, quantity of fertilizer, herbicides, land ownership , seed acquisition mode), I is a vector of institutional variables (membership in a professional organization, participation in training sessions, access to credit), and ε_i is the error term that is assumed to be normally distributed.

Equation 5 can be estimated by a Tobit model under the assumption that the error term is assumed to be normally distributed with zero expectation (Tobin, 1958). However, the Tobit model assumes that the effect of a variable does not vary from the adoption decision to the adoption intensity equation. Given this restrictive assumption, we adopted an extension of the Tobit model by Cragg (1971). The latter estimates a double hurdle model by assuming that the adoption decision can be estimated by a Probit model, while the adoption intensity allocation equation follows a truncated normal distribution. Following the work by Bezu et al. (2014), the double hurdle model is specified as follows:

$$\begin{cases} AOC_{i1}^* = \eta_{01} + \eta_{11} X_i + \eta_{21} T_i + \eta_{31} I_i + \varepsilon_{i1} \; \textit{Adoption decision with } \varepsilon_1 \sim N\left(0,1\right) \\ AOC_{i2}^* = \eta_{02} + \eta_{12} X_i + \eta_{22} T_i + \eta_{32} I_i + \varepsilon_{i2} \; \textit{Adoption intensity with } \varepsilon_2 \sim N\left(0,\sigma^2\right) \end{cases} \quad (6)$$

$$AOC_i = f\left(x, \varepsilon_2\right) \text{ if } AOC_{i1}^* \succ 0 \text{ and } \text{AOC}_{i2}^* \succ 0$$

Where AOC_{i1}^{*} is a latent variable referring to the producer's probability of adopting organic cotton, AOC_{i2}^{*} is also a latent variable designating the intensity of adoption and AOC_i is an observed variable measuring the area allocated to organic cotton production. We estimate the Cragg model using the maximum likelihood method.

2.3.2. Controlling endogeneity in adoption

Membership of a professional organization and participation to the training sessions may be endogenous in the adoption equations. Indeed, non-observed factors specific to producers (motivations, leadership, etc.) may affect both the allocation of organic cotton acreage and membership in a professional organization and participation in training sessions. Similarly, there may be double causality between adoption and membership in a professional organization and participation in training sessions. To that respect, we follow the two-step procedure of Wooldridge, (2014). The first step consists in regression of the endogenous variables such as professional organization membership and training session attendance on a vector of exogenous variables using the Probit model. From this first step, we predict the generalized residuals[2] associated with each equation as follows:

$$\hat{gr}_{i2} = y_{i2}\lambda\left(z_i\hat{\beta}_2\right) - \left(1 - y_{i2}\right)\lambda\left(-z_i\hat{\beta}_2\right) \quad (7)$$

Where $\hat{gr}_{i2}$ are the generalized residuals, y_{i2} is the endogenous variable, and $\lambda(.)$ is the inverse Mills ratio from the first stage. The second step consists of introducing the predicted generalized residuals into the structural equation. The significance of the coefficients associated to the generalized residuals through the t-test rejects the null hypothesis of exogeneity of membership to a professional organization and participation in training sessions (Wooldridge, 2014).

2.3.3. Adoption Impact Model

Let W denote the welfare index of producers i:

$$W_i = \beta_0 + \alpha AOC_i + \beta_1 X_i + \beta_2 T_i + \beta_3 I_i + \varepsilon_i \quad (8)$$

Where AOC_i denotes the adoption of organic cotton by producer i, and ε_i is the error term. Following the empirical literature (Zeng et al., 2015), we assume that organic cotton adoption is expected to improve producer welfare through improved productivity and income.

Furthermore, the adoption model (equation 6) may suffer from endogeneity problems given the presence of unobservable factors that motivate some producers to adopt than others. To solve this potential endogeneity problem, we followed the approach adopted by Bezu et al. (2014) and Verkaart et al. (2017) in estimating equation 8. Thus, we use the predicted values of organic cotton area from the double hurdle model as the instrument for organic cotton area in equation 6. This approach is more robust and efficient than the standard double least -squares approach (Bezu et al., 2014; Wooldridge, 2002).

3. Results and discussion

3.1. Descriptive statistics

[2] The generalized residuals are the generalization of the standard linear model residuals in non-linear models such as binary, count, and fractional responses, see (Gourieroux et al., 1987) for further details.

This section presents the summary statistics of the variables of the study. Table 1 presents the proportion of cotton farmers who adopted organic cotton by gender and place of residence.

Table 1: Distribution of organic cotton adoption

Organic Cotton	**Total**	**Gender**		**Region**		
		Male	**Female**	**Alibori**	**Atacora**	**Collins**
Adopter (%)	23.38	83.70	16.30	69.80	6.30	23.90
Non-adopters (%)	76.62	92.70	7.30	53.00	28.10	18.90
Sample size	1416	1283	133	806	326	284

The results in Table 1 show that 23.38% of producers have adopted organic cotton production, indicating a low level of adoption of organic cotton in Benin. Among these adopters, 16.30% were women compared to 83.70% of men. This indicates a higher propensity of men to adopt organic cotton than women. Similarly, the adoption of organic cotton among the different regions of Benin is asymmetric. In particular, 70% of cotton producers residing in Alibori have adopted organic cotton production compared to 24% and 6% respectively for Collines and Atacora districts. These results could be explained by the fact that Alibori region was the most producer of cotton in Benin. These results suggest a potential correlation between producer size and the adoption of organic cotton or the existence of externalities in the adoption of organic cotton.

Table 2 presents the socio-demographic, economic, and technical differences between organic cotton adopters and non-adopters. We notice the existence of a statistically significant difference between the two groups of producers in terms of place of residence, age, gender, soil fertility, mode of seed acquisition, ownership of land, as well as transportation costs, membership in a professional organization, and participation to the training. Similarly, there is a significant difference in income and poverty levels between the two groups of producers. Surprisingly, these results imply that - conventional cotton producers have higher incomes (about 4 times) than those who have adopted organic cotton. This low net income of organic cotton producers is surprising because we expected a greater income compared to non-adopters. Similarly, our results show that the incidence, depth, and severity of poverty are all high among organic cotton farmers compared with conventional cotton farmers. In contrast, our results show that there are no statistically significant differences in terms of education and experience of producers, herbicide use, and access to credit and selling price of cotton.

Before estimating the adoption and impact models, we've checked for multi-collinearity issues. Indeed, the correlation matrix (Table A1) revealed the existence of high correlations between explanatory variables, notably between age and years of experience (correlation coefficient equals to 0.70). Such correlations may lead to bias in our results due to the presence of multicollinearity. Furthermore, the inclusion of the age and years of experience squared are likely to increase the likelihood of multi-collinearity. Hence, we performed the variance inflation factor test for both the adoption and the impact equations. The results indicated that when including both the square of age and experience, the VIF statistics were (Table A2.2 and Table

A3.2 in the appendix) greater than the threshold of 10, implying that there were multi-collinearity issues. Consequently, we removed the age squared from the regressions to handle the multi-collinearity issue (Table A2.1 and Table A3.1 in the appendix).

Table 2: Characteristics of adopters and non-adopters

Variable	Adopters	Non-adopters	t-test/Chi-2	P-value
Region (Alibori=0; Atacora=1; Collines=2)	1.541	1.659	-2.370	0.018
Gender (reference=female)	0.837	0.927	-4.970	0.000
Age (Years)	43.429	41.292	2.960	0.003
Education (reference=no education)	0.347	0.318	0.740	0.459
Experience (years)	14.598	14.982	-0.670	0.503
Land ownership (reference=no)	0.961	0.982	-2.330	0.020
Seed gift (reference=no)	0.997	0.973	2.630	0.009
Fertile land (reference=no)	1.214	0.992	6.010	0.000
Fertilizer use (number of applications)	1.9758	1.1401	42.53	0.000
Herbicides (number of applications)	0.976	0.977	-0.120	0.905
Transportation cost	1403.800	2977.200	-3.580	0.000
Cotton sale price	326.280	1936.900	-0.960	0.339
Number of organization	1.359	1.248	2.950	0.003
Access to credit (reference=no)	0.142	0.168	-1.110	0.266
Training (reference=no)	0.453	0.292	5.510	0.000
Income	157.34	591.07	-6.990	0.000
Poverty incidence	0.900	0.653	8.940	0.000
Poverty gap	0.806	0.524	10.710	0.000

3.2.Adoption model estimation results

The results of the estimation of the double -hurdle adoption model are presented in Table 3. Before interpreting these results, we ensure the overall validity of the model which was evidenced by the significance of the Chi-2 statistic in the adoption equation and that of the adoption intensity. In addition, our results indicate that the coefficients of the generalized residuals for membership to the professional organization are not significant, implying the exogeneity of this variable in the model (Table A4 in the appendix). However, the coefficients of the generalized residuals for the participation in the training session's equation are all significant in both the adoption model and the organic cotton acreage allocation model (Table A5 in appendix). These results indicate that participation in training sessions is endogenous and that the issues should be handled. Our results indicate that participation in training sessions increases the probability of adoption of organic cotton and the area allocated to organic cotton. These results could imply that the training sessions are effective channels through which farmers are informed about organic cotton technical itineraries. Our results are consistent with the existing literature on the determinants of agricultural technology adoption in developing countries (Ahmed & Mesfin, 2017; Lampach et al., 2019; Martey et al., 2019; Verkaart et al., 2017).

Tableau 3: Cragg's Double Hurdle model

Variable	Adoption equation	Intensity adoption equation

	Coef.	St. Err.	Coef.	St. Err.
Gender (reference=female)	1.231***	0.281	1.395***	0.400
Age	-0.129***	0.040	-0.167***	0.047
Education (primary or secondary=1)	-0.450***	0.178	-0.349	0.252
Education (Higher =2)	0.121	0.225	0.163	0.308
Experience	0.101***	0.031	0.164***	0.0421
Experience squared	-0.001	0.001	-0.001	0.001
Region of residence (reference=Alibori)				
Region (Atacora=1)	-4.326***	0.717	-7.054***	1.120
Region (Collines=2)	-6.650***	1.457	-10.621***	2.269
Land ownership (reference=0)	1.996***	0.787	1.904*	1.119
Seed gift (reference=0)	1.144	1.004	4.699***	1.555
Land Fertility (reference=0)	1.043***	0.373	0.889*	0.499
Fertilizers (number of applications)	1.653***	0.353	2.313***	0.569
Herbicides (reference=0)	-0.822	0.522	-1.808***	0.754
Transportation cost	-0.0445***	0.009	-0.071***	0.0145
Membership professional organization ((number of organization)	-0.962***	0.251	-1.469***	0.394
Access credit (reference=no)	0.646***	0.207	0.598**	0.285
Training (reference=no)	0.429***	0.143	0.552***	0.194
Generalized residuals (Membership professional organization)	12.465***	2.994	22.419***	4.674
Generalized residuals (Training)	12.459	9.419	-2.683	12.782
Intercept	-12.639	7.669	-5.154	10.283
Sigma	-	-	1.838	0.076
Log likelihood	-737.074		-807.620	
Chi-2(21)	262.332		885.830	
Number of observations	1412		1412	
Bootstrapping replication	1000		1000	

Significance level: *** (1%) ; **(5%) ; *(10%)

Our results also revealed that the adoption and intensity of adoption depend on farmers' experiences, age, land ownership, fertilizer use, access to credit, membership in professional organizations, and participation to training session. In fact, experienced producers tend to allocate more land to organic cotton production, while age negatively affects the organic cotton acreage allocation. On the other hand, landowner producers allocate less acreage to organic cotton production compared to non-landowners. Being a member of a professional organization and participating to training sessions also had a positive effect on the adoption and intensity of the adoption. These results support the contention that training improves farmers' knowledge of new technologies (Conley & Udry, 2010). Access to credit affects negatively the adoption of organic cotton and the allocation of organic cotton acreage produced. This result, although contrarily to our expectations, can be explained by the fact that bank and microfinance institutions were reluctant to finance agricultural projects due to the existence of several risk factors. The price of transport also has a negative effect not only on the adoption of organic cotton but also on the allocation of land.

3.3.Impact of organic cotton adoption on welfare

The results of the estimation of the impact models of organic cotton adoption are presented in Table 4. We estimated the impact of adoption by considering respectively producers' net income (Income model), the poverty incidence model and poverty gap model as welfare measures. We estimated a linear instrumental variable model for the income and poverty gap models. For the poverty incidence model, we estimate a Probit model with instrumental variables. Our results showed that organic cotton acreage has a negative impact on welfare regardless the measure used. In particular, a 10% increase in organic cotton production leads to a 7.76% decrease in income and increases the probability of falling below the poverty threshold by 9.15%.

3.4.Effect of control variables

The results of the impact models presented in Table 4 indicate the existence of regional heterogeneity in the impacts of organic cotton production on producers' income. In particular, organic cotton production in Collines and Atacora regions improves the income and poverty level of producers more than in the Alibori region. We also show that land fertility, membership of a professional organization and access to credit allow producers to rise above the poverty level through the improvement of farmers' income. Our results align with several other existing studies (Ahmed, 2022; Ahmed & Mesfin, 2017; Manda et al., 2016; Martey et al., 2019).

Tableau 4: welfare impacts of organic cotton

Variable	Income		Poverty incidence		Poverty gap	
	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.
Ln(Area under organic cotton)	-0,776***	0,117	0,915***	0,213	0,161***	0,026
Gender (reference=female)	0,028	0,341	-0,249	0,297	-0,012	0,083
Age	0,03	0,057	-0,018	0,044	-0,005	0,011
Education (primary or secondary=1)	0,255	0,264	-0,158	0,191	-0,02	0,061
Education (Higher =2)	0,311	0,302	-0,179	0,241	-0,073	0,071
Experience	-0,051	0,042	0,008	0,031	0,009	0,009
Experience squared	0,001	0,001	0.000	0,001	0.001	0.000
Region of residence (reference=Alibori)						
Region (Atacora=1)	1,202***	0,2	-0,347*	0,186	-0,29***	0,051
Region (Collines=2)	0,543*	0,279	-0,009	0,227	-0,156**	0,066
Land ownership (reference=0)	0,385	0,782	-0,252	0,432	-0,043	0,174
Seed gift (reference=0)	0,295	0,438	-0,453	0,37	0,01	0,106
Land Fertility (reference=0)	0,398	0,249	-0,318*	0,176	-0,079	0,054
Fertilizers (number of application)	0,112	0,234	-0,245	0,191	-0,041	0,053
Herbicides (reference=0)	0,535	0,454	-0,638	0,535	-0,137	0,108
Transportation cost	0,122	0,106	-0,123	0,077	-0,045*	0,023
Membership professional organizations (number of organizations)	0,51***	0,161	-0,326***	20,114	-0,097***	0,037
Access credit (reference=no)	0,681***	0,251	-0,481**	0,191	-0,124**	0,057
Training (reference=no)	-0,494**	0,232	0,269	0,169	0,134**	0,052
Intercept	8,325***	1,423	3,309***	1,159	1,072***	0,303

Significance level: *** (1%) ; **(5%) ; *(10%)

3.5.Discussion

The main goal of this study was to investigate the impact of the adoption of organic cotton on farmers' welfare in Benin. Our results showed that the adoption of organic cotton decreased farmers' income and an increase in the poverty rate and poverty incidence among adopters. These results imply that organic cotton significantly hurts farmers' welfare. Our findings are surprising because contradict the theoretical literature on innovation adoption in agriculture. In particular, Janvry et al. (2016) argued that the adoption of technological innovation in agriculture improves farmers' welfare through improvement in productivity, income, and consumption. Even more, much empirical evidence supports these externalities of the adoption of technological innovation in agriculture (Ahamed (2022); Martey et al. (2019), and Verkaart et al. (2017).

For instance, using multinomial endogenous switching regression to control for selection bias along with the propensity score matching method, Ahmed (2022) concluded that the adoption of a new variety of maize and inorganic fertilizers significantly increased yield and welfare in eastern Ethiopia for 35.26%. Martey et al. (2019) used the same approach used by Ahamed (2022) to assess the impact of new fertilizer on productivity and farmers' income in Ghana. The authors found that the adopters gained 55% increase in yield and 30% improvement in income.

Although our findings are contrary to both theoretical and empirical literature, several explanations may be provided regarding the context of the study. First, organic cotton producers do not master the production techniques related to organic cotton. Indeed, organic cotton production strictly prohibits the use of chemical fertilizers, pesticides, and the use of genetically modified cotton seeds. The production of organic cotton does not mean the substitution of chemical inputs for natural inputs but rather compels a set of principles and techniques. One of the main principles in biological cotton is the natural management of the soil fertility and crop nutrition, in with the main strategies being organic manure, crop rotation and inter-row cropping, anti-erosion management, and water conservation.

A second principle is the natural management of pests and diseases, which is mainly based on systematic prevention, biological pest control, and permanent crop monitoring Helvetas (2008). In addition, organic cotton is more labour-intensive and farmers should have deep technical knowledge of the production. This is why producers must first have good apprenticeship in organic farming techniques and continuous guidance during the first years of production. The success of a farmer depends essentially on his understanding of the natural processes and cycles of plants, soil, pests, and beneficial animals.

For instance, Manda et al. (2016) argued that an organic cotton farmer must be a continuous learner to build the capacity to master production techniques and improve production performance. Consequently, the negative impacts of the organic cotton adoption in this study could be explained by the lack of training and investment that are required before expecting significant improvement in yield and farmers' income. This assumption is more likely because Benin government does not support the adoption of organic cotton in Benin. Therefore, the agricultural sector is mainly practiced by farmers with a low educational level, and where the knowledge is acquired by doing within the household. Our findings are supported by Manda et al. (2016), who showed that the adoption of an agricultural technology package by rural producers in Zambia significantly increased yields. However, they revealed that the welfare impacts of the adoption were limited by the costs of accessing the technologies.

4. Conclusion

This paper examined the determinants of the adoption of organic cotton and its impacts on farmers' welfare in Benin. Using a sample of 1416 cotton farmers from Benin, Cragg's double hurdle model is used to determine the drivers of organic cotton adoption. Our results revealed that the allocation of organic cotton acreage depends on the producer's place of residence, experience, age, land ownership, fertilizer use, access to credit, membership in a professional organization, and participation in training. We evaluated the impacts of the adoption on farmers' welfare using the instrumental variables based-approach.

The results surprisingly showed that organic cotton hurt farmers' welfare through a decrease in annual net incomes and an increase in poverty incidence and poverty gap. The results could be explained by a lack of training on the new agricultural innovation. Our findings lead to agricultural policy implications, notably for the sustainable use of lands and for the achievement of the first sustainable development goal that aims the reduction of extreme poverty rate by 2030. Hence, to promote the adoption of organic cotton, the Benin government needs to design targeted training programs toward cotton producers.

Equally, the design of targeted subsidy policies, notably for seeds and fertilizers, could promote the adoption of agricultural technological innovations on the one hand and increase the efficacy of the adoption. Moreover, interventions aiming to promote and secure land ownership should be designed. Agricultural and rural financial services need to be democratized to limit the financial constraints to agricultural innovation adoption. One of the main contributions of this study was the shed light on the drivers and impacts of an innovation that is at the pilot stage. However, our findings are limited by the fact that the data generation process was not based on a randomized control design. Further research may handle this issue.

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