

Impact of the Adoption of Electrical Equipment on Cotton Productivity in Benin

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Abstract

In Benin, the improvement in cotton productivity occurred in a context of increased access by farmers to electrical equipment. The objective of this research is to analyze the effective contribution of the adoption of electrical equipment to cotton productivity in the country. The regime switching model – MCR (*endogenous switching regression*) is used based on data from the Harmonized Survey on Household Living Conditions in Benin (EHCVM, 2019). The results obtained indicate on the one hand that education, use of telephone, financial account, inputs, transfers received, household shock and cultivation area are determining factors in the adoption of equipment electricity by cotton producers and on the other hand that the value of the effect of the adoption of electrical equipment on cotton productivity is 2502 kg per ha. This gain in productivity suggests at the microeconomic level that cotton producers who have not adopted electrical equipment do so in the hope, all other things being equal, of an increase in their productivity on average of 44.31% compared to their level current productivity. The microeconomic policy implications of this study are the orientation of cotton farmers towards equipment using electrical energy and the popularization of their adoption, especially in areas of intense production for the increase in cotton productivity in Benin.

Keywords: Energy, productivity, cotton, MCR, Benin.

JEL codes: Q42, Q12, C26

1. Introduction

The functioning of the global economy and, in particular, competition from new emerging markets are directing production objectives towards more sophisticated products with high technological content (Dumas and Fumba, 2021). It makes the capacity for innovation the fundamental element of competition. In this new era, economic systems as a whole are under increasingly severe pressure, which finds its originality in the complexity of cross-border networks of flows of knowledge, ideas, and diverse technologies (González Blanco et al, 2018). The agricultural sector is not spared from increased mechanization, with various more efficient production systems with high energy requirements. This innovation, whatever its nature, constitutes a key factor in economic growth in general (Krugman, 1990) and in the growth of agricultural productivity in particular.

In Benin, over the last decade, improvements in cotton productivity have occurred in a context of increased farmer access to electrical equipment. Like many countries in West and Central Africa, the Beninese economy is based on the production and export of cash-rich products, of which cotton attracts the particular attention of decision-makers and development partners (Amonmide et al, 2019). Since the 2018-2019 cotton campaign, Benin has been ranked as the leading cotton producer in Africa, with production reaching 766,000 tonnes in 2022. Achieving this performance is favoured by several reforms undertaken by the State whose policies put in place aim, among other things, to develop monitoring of the production of electrical energy from natural gas through the construction of hydroelectric power stations to support technological production innovations (MCVDD, 2019).

Indeed, the electrical energy coverage rate increased by 11.8% between 2015 and 2020, in line with the good performance of cotton production, which has continued to reach record levels since 2016 (WDI, 2021). Thus, in addition to direct modern factors of production such as fertilisers, pesticides, insecticides and herbicides, electrical equipment plays an important role in cotton production in Benin, especially in a context of climate change where the treatment of plants is obligatory. First, the use of these modern factors requires electrical energy (EHCVM, 2019). The pumping of groundwater for irrigation and drinking water in fields essentially depends on the supply of electrical energy (Ali et al, 2016). Other agricultural activities, such as sowing, spraying, weeding, harvesting, and drying, also require adequate energy sources to increase agricultural productivity. Thanks to new tools and products, clearing is done by spraying the grass using devices that use electrical energy. Also, electrical devices are used for weeding through the use of herbicides, as well as spraying against insect pests with the use of insecticides, which requires electrical energy.

However, although an electrification effort is being made by the government, the rate of electrical energy coverage still remains insufficient to support this cotton production in Benin. This is justified by the fact that the conventional energy supply does not constitute the most appropriate electrification option in developing countries, and particularly in rural areas (Abeberese, 2017). Thus, despite the improvement in access to electricity for rural populations, the rate of which rose from 10.6% in 2010 to 17.2% in 2017, the electrification of agricultural cultivation areas remains to be desired. Due to the unfavourable cost-effectiveness of extending the electrification network in sparsely populated remote areas whose demand for electricity is relatively low compared to urban areas, only 18.2% of the rural population has access to electricity. Electrical energy in 2020, while 66.1% of the urban population has access to electricity compared to 41.4% nationally (Banque Mondiale, 2022).

In 2017, out of 5,853 farmers surveyed by the World Food Program in Benin, 11.62% had access to electrical energy with the adoption of electrical equipment in the agricultural production system. This adoption of electrical equipment was accompanied by an improvement in cotton productivity in Benin. The main export crop, cotton, saw its production fluctuate between 427,000 and 451,124 tons during the 2004-2016 campaigns before experiencing a significant increase, reaching the record level in Africa of 766,000 tons in 2022 (DGAE, 2022). What is the effect of the adoption of electrical equipment on cotton productivity in Benin? The objective of the study is to evaluate the effect of the adoption of electrical equipment on cotton productivity in Benin.

In the economic literature, the relationship between the adoption of electrical equipment and agricultural productivity is debated through the transmission channel from economic growth to agricultural productivity (Cole and Frazier, 2018; Hakimah et al, 2019). In a unidirectional sense, Tenezakis and Tritah (2020) show that the adoption of electrical equipment is closely linked to social and economic development. Hakimah et al. (2019) find that energy constitutes a very decisive production input in the sense that it makes it possible to increase the efficiency of other production factors such as machines and processing devices. For Abeberese (2017), electricity constraints can limit a country's growth by pushing companies to operate in industries with fewer opportunities for productivity improvement. According to Felloni et al. (2001), the adoption of electrical equipment is crucial for agricultural modernization and economic growth. On the other hand, the conclusions of the study carried out by the General Directorate of Economic Affairs (DGAE) in 2020 on the situation of electrical energy in Benin and its implications on the national economy, confirm the existence of a feedback between the adoption of electrical equipment and Gross Domestic Product (GDP) per capita in the long term. The absence of a significant relationship between the adoption of electrical equipment and agricultural productivity is affirmed by the findings of Kpemoua

(2017) after analyzing the impact of electrical energy on the economic growth of Togo.

From all this work, knowledge on the link between the adoption of electrical equipment and cotton productivity in the context of Benin is almost non-existent. This study, therefore, appears to be a contribution to the debate in this area. To contribute to the empirical literature and the policy document, this study questions the effects of the adoption of electrical equipment on cotton productivity in Benin. Originally, the article uses the econometric method that can make it possible to evaluate the real effect and the counterfactuals of improving cotton production in Benin. To do this, this article is organized as follows: the first section is devoted to the objectives and hypotheses, the second to the study context, the third to the literature review, the fourth to the conceptual framework and the other four sections are dedicated respectively the methodology of the study, the data and descriptive analyses, the results obtained and the conclusion.

2. Objectives and Hypotheses

The general objective of the article is to analyze the effect of the adoption of electrical equipment on cotton productivity in Benin. This involves, in particular, on the one hand identifying the explanatory factors for the adoption of electrical equipment and on the other hand, determining the gain in cotton productivity linked to the adoption of electrical equipment. To achieve these objectives, two research hypotheses are formulated. The first stipulates that the educational level of the cotton producer is, among other things, a factor that determines the adoption of electrical equipment while the second postulates that the adoption of electrical equipment generates a gain in cotton productivity in Benin.

3. Study Context

National energy consumption is relatively low in Benin. It has a consumption structure marked by the predominance of traditional uses of biomass energy. The consumption of fuelwood and charcoal represents approximately 51% of the total final energy consumed in 2015, petroleum products 47% and electricity less than 3%. But the demand for electrical energy has experienced relative growth over the same years, with a high rate of national electrification. In rural areas, this rate increased from 11.1% in 2015 to 18.2% in 2020. Benin's electricity supply is ensured through two main sources, namely: national production and imports. Before 2016, the country did not have domestic sources of electricity generation. Even until 2020, Benin's national energy situation is characterized by a very low internal electricity production capacity, which places it in great dependence on certain neighboring countries such as Nigeria, Ghana, and the Coast. of Ivory for its supply.

According to DGE (2015), national electricity production, which is increasing compared to previous years, amounted to 323 GWh in 2015. However, this production remains very insufficient compared to a total national electricity requirement of 1378 GWh, i.e, a dependence rate on electricity imports of 76% for this year. While Benin has a relatively significant potential in renewable energies which can be exploited to reduce this dependence.

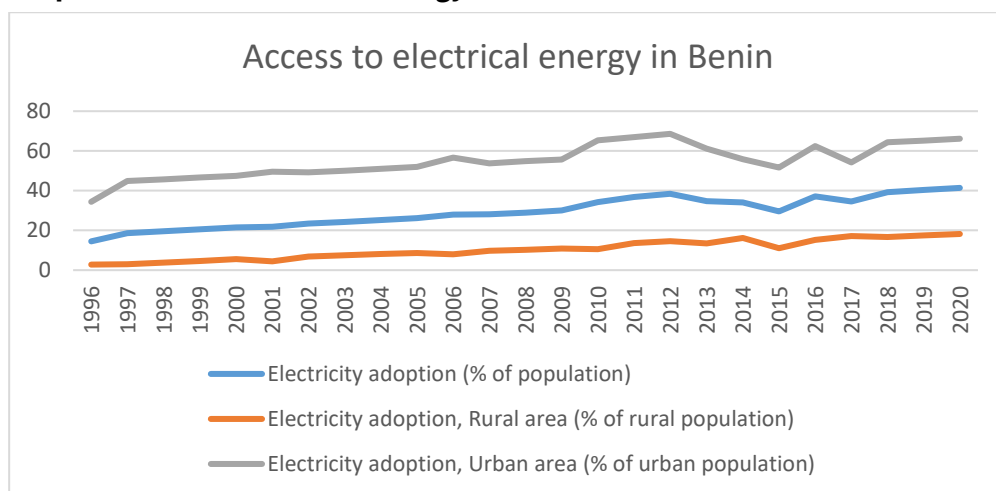
The hydroelectric potential is estimated at least 400 MW for the main dam construction sites for which project studies have been carried out. Indeed, a probable increase or decrease in water resources could have impacts on hydroelectric production. The available and economically exploitable potential with regard to the possibilities for valorising wind energy resources remains to be determined. The penetration of renewable energies in electricity supply is still very low (3.4% in 2015).

To reduce the shortage of electrical energy and make quality and reliable energy available to households and businesses, the public authorities have developed an action plan, which has been implemented through reforms of businesses. To support these actions, projects are implemented and relate to: increasing national production capacities; the development of means of transport and distribution of electrical energy; the development of rural electrification; the development of renewable energies and energy efficiency. The implementation of these projects allowed Benin to increase its production capacity and to have in 2019, its own additional production capacity of around 177.5 MW. In terms of the development of electrical energy transport and distribution networks, Benin has acquired and installed 120,000 connection kits for the benefit of subscribers of the Société Béninoise d'Énergie Electrique. Concerning renewable energies, notable progress has been recorded and has enabled the construction of four (04) solar power plants with a total capacity of 50 MW in Bohicon, Parakou, Djougou and Natitingou, the construction of the 25 MW in Pobè, and that of 10 MW in Kandi. These various projects have improved energy performance and affected the energy coverage rate. This improvement in energy performance was accompanied by increased performance in the agricultural sector.

The performance noted in agriculture resulted in an increase of 4.9% in 2019 compared to -1.0% in 2015. This increase in the added value of the agricultural sector results from the regular increase in performance without precedent recorded by cotton production. Cotton production would increase by 72.55%, reaching 678,000 tons in 2019 compared to an achievement of 392,912 tons for the 2014/2015 cotton campaign, ranking the leading producer country in Africa. It continues its remarkable and continuous growth, allowing Benin to maintain its rank as the leading African cotton producing country (PR-PICA4, 2022). Cotton production stood at 766,000 tons in 2022, an increase of 7.36% mainly driven by an improvement in yields of more than 15% compared to 2019. This new production

record is the consequence of: i) the effectiveness of the supervision and guidance system on the adoption of new farming techniques; ii) the provision of specific credits for cotton production; iii) the implementation at the right time and in sufficient quantity of quality inputs; iv) photo-calcic amendment actions (soil recovery manure); v) strengthening training for producers on the use of energy and similar devices; and vi) improving the overall governance of the sector, etc. Graphs 1 and 2 best reflect the evolution of electric coverage and cotton production in Benin.

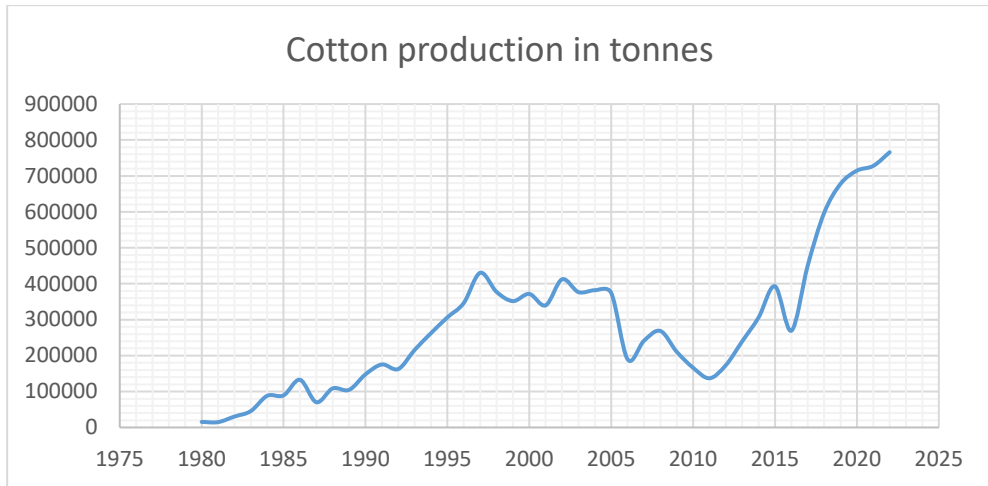
Graph 1: Access to electrical energy in Benin



Source: Authors based on World Bank data, 2021

Graph 1 presents the state of access to electrical energy at the national, urban, and rural levels from 1996 to 2020. The graph provides information on the government's growing efforts in terms of supplying electrical energy in Benin. With a 14.5% rate of access to electricity in 1996 at the national level, the access rate is 34.4% in urban areas compared to 2.8% in rural areas. This gap is maintained until 2012 with an increasing supply effort in both urban and rural areas reaching 68.6% and 14.6% respectively before falling in 2015 to 51.7% and 11.1% respectively. Thanks to the Electric Network Extension and Densification Project (PEDER), the rate of access to electricity rose to 41.4% at the national level, with 66.1% in urban areas compared to 18.2% in rural areas. It should be noted from these statistics that electricity remains inaccessible to a large part of the Beninese population, especially in peri-urban and rural areas, with a consequence on the dominant agricultural activities in these areas. Rural electrification being a priority project of the government, the Rural Electrification Project (PERU) was launched in 2021 to power new rural localities and the extension of the network in peri-urban localities.

Graph 2: Evolution of cotton production



Source: Authors based on APRM data, 2022

Before independence, statistical data on cotton were non-existent or sometimes fragmentary. From 1960 to 2022, the cotton sector has evolved irregularly, presenting three major trends. The first increasing trend from 1980 to 1997, the second decreasing from 1997 to 2011, and the third increasing from 2011 to 2022. This evolution is linked to the context of production, which depends on political, economic, and climatic factors.

For the first trend, although the trend is growing, this growth is irregular over the years. Thus, from 1960 to 1972, under the leadership of the French Textile Fiber Development Company (CFDT) and the Technical Insurance and Cooperation Company (SATEC), cotton production recorded regular growth and was multiplied by 17.17 going from 2900 tons to 49795 tons thanks to the availability of inputs and the improvement of technical supervision. In the era of the revolution and under the influence of the government's new agricultural policy focused on the development of food crops, cotton production declined to reach 16,116 tons in 1977. In 1979, the cotton sector returned to new growth reaching 27,000 tons. But this growth quickly faded following the use of an ineffective insecticide. It was only in 1983, thanks to the organization of the sector via the start of the Borgou and Zou development projects, the establishment of new price stabilization and support rules and the clarification of the role of Regional Action Centers for Rural Development (CARDER) and the National Society for Agricultural Promotion (SONAPRA) that the sector got back on track with a production of 132,762 tons in 1983. In 1987, again, due to the continued decline in world cotton prices, the poor rainfall observed, the removal of subsidies on inputs and the inefficient management of the sector, production experienced another fall of 47.4%. But the revival of production and its progression will take place quickly from 1990,

following the application of restructuring measures initiated within the sector in a context of economic liberalism and the significant rise in the purchase price of seed cotton until 1997.

From 1997 to 2011, the sector experienced a continuous decline linked to a major political transition. Production fell by 214% from 430,398 to 136,958 tons. On the other hand and for the third trend, cotton production resumed its unprecedented growth of 395%, reaching 678,000 tons in 2019 compared to an achievement of 136,958 tons for the 2010/2011 cotton campaign, ranking the country as the leading producer of cotton. 'Africa. This is favorable thanks to the technological reforms and innovations brought to the sector, the strengthening of training for producers on the use of energy and similar devices, as well as the improvement of the overall governance of the sector. Until the last campaign, Benin maintained its place as Africa's leading producer with production reaching 766,000 tons in 2022.

4. Literature Paper

In the economic literature, the relationship between the adoption of electrical equipment and agricultural productivity is debated through the transmission channel from economic growth to agricultural productivity (Cole and Frazier, 2018; Hakimah et al, 2019). Tenezakis and Tritah (2020) analyze the relationship between the adoption of electrical equipment and agricultural productivity in a unidirectional sense by concluding on the level of electrical energy essential for the development of a country. Combined with sanitation, they are key factors in ensuring economic development and the quality of life of the population of any nation through the productivity of economic actors (Mensah et al, 2021). Sub-Saharan Africa is the only area in the world where the number of households without electricity increases each year due to rapid population growth (Feng and Liu, 2018). Due to the important role that the agricultural sector plays in sustaining growth and reducing poverty in developing countries, the adoption of practices that can simultaneously improve agricultural productivity while minimizing environmental impacts is essential (Lokonon and Mbaye, 2018).

Electrical energy constitutes a very decisive production input in the sense that it makes it possible to increase the efficiency of other production factors such as machines and processing devices (Hakimah et al, 2019). From this point of view, an insufficient electrical energy can lead to difficulties in production, in meeting delivery times, in satisfying demand, and generate economic losses for production stakeholders. In their study on Pakistan, Ali and Behera (2016) showed that alternative energy sources have positive and significant impacts on the productivity of wheat, rice, and corn crops and on household income. The use of alternative energy sources for water pumping has led to a reduction in household poverty. Andersen and Dalgaard (2013) confirm using macroeconomic data on a set of sub-Saharan African countries that power outages constitute a substantial

brake on economic growth. Thus, electricity constraints can limit a country's growth by pushing companies to operate in industries with fewer opportunities for productivity improvement (Abeberese, 2017).

In many developing countries, most income-generating activities are carried out in small businesses, which generally are not able to fully insure themselves against power cuts, especially when fixed adaptation costs are high. As a result, frequent interruptions in electricity supply due to outages can have a significant impact on how workers and businesses can use their resources for production and generate income. Electricity shortages then reduce companies' revenues and therefore negatively affect their performance (Fisher-Vanden et al. 2015; Allcott et al. 2016).

Business performance is linked to true adoption and quality adoption of electric power, particularly in energy-intensive industries. The lack of safe and reliable electrical energy is a constraint for peaceful investment in developing countries. Cole and Frazier (2018) show using World Bank data that there is a negative relationship between unreliable electricity supply and business sales, with a stronger effect for businesses that do not have stopgap measures in the event of disruptions to the distribution networks. For Deleidi, et al. (2020), in the absence of empirical evidence, conflicting theoretical arguments claim that public investments “crowd out” or “attract” private investors. The authors showed that the macroeconomic concept of crowding out is inapplicable to sectoral studies such as electricity. Using FGLS and static and dynamic GMM estimators, they found that public investments not only have a positive but also consistently the largest effect on private investment flows compared to feed-in tariffs, taxes, and standards energy portfolio in general, and for wind and solar technologies separately.

On the other hand, the conclusions of the study carried out by the General Directorate of Economic Affairs (DGAE) in 2020 on the situation of electrical energy in Benin and its implications on the national economy, confirm the existence of a feedback between the adoption of electrical equipment and GDP (Gross Domestic Product) per capita in the long term. The absence of a significant relationship between the adoption of electrical equipment and agricultural productivity is similarly affirmed by Kpemoua (2017) after the analysis of the impact of electrical energy on the economic growth of Togo.

Addressing the question of the determinants of the adoption of electrical equipment, Ahn et al. (2013) identified cost, limited knowledge and skills, adoption habit of old energy sources as the main barriers related to their adoption. Chan et al. (2016) found resistance to change, higher costs of solar energy, lack of knowledge and awareness, lack of expertise and government incentives. Hwang and Tang (2012) and Hwang and Ng (2013) similarly demonstrated that higher costs of solar equipment, lack of interest and communication from market players on demand and supply are factors that limit the adoption of modern technologies

including electrical energy. For Hwang et al (2017), it is the higher initial costs and the lack of government support that influence energy adoption in Singapore.

In Benin, according to Assouto and Houngbèmè (2023), the increase in agricultural productivity is linked to producers' access to credit. Weak agricultural financing prevents producers from acquiring the modern technologies essential to the development of their activity. Furthermore, agricultural productivity is negatively influenced much more by precipitation and temperature variations in the South than in the North of the country (Nonvide and Akpa, 2023). Using the production function associated with a panel data model covering 76 of the 77 communes of Benin over the period from 1995 to 2019, this work used impact evaluation methods. On the other hand, Hounnou et al. (2019) exploit a dynamic general equilibrium model to explain the loss of agricultural productivity attributable to climate change. In another sense, using a vector error correction model (VECM), Nadjib et al. (2022) attested to the existence of a positive link between cotton productivity and economic growth in Benin.

This literature, although rich and abundant, has not dealt with the effect of the adoption of electrical equipment on agricultural productivity in Benin, much less on cotton productivity. It focused more on the effect of energies on the productivity of firms in industry (Dumas and Fomba, 2021; Abeberese, 2017) and economic growth as well as on the factors of increasing agricultural productivity in its together (Assouto and Houngbèmè, 2023; Nonvide and Akpa, 2023; Hounnou et al, 2019). This article will certainly complement the existing literature.

5. Conceptual Frame

The literature has developed a conceptual framework that makes it possible to measure agricultural productivity in three ways, namely total factor productivity, technical efficiency, and yield. This study uses yield as a measure of agricultural productivity. The theoretical basis on which the model of this study is based is the Cobb-Douglas type production function, which establishes the relationship between inputs (labor (L); capital (K)) and a given level of production Q. In the study, by adopting the Cobb-Douglas production function, labor (L), as agricultural employment, and capital (K), as physical or financial, were both included as agricultural production inputs. In addition to these two factors, there are other explanatory variables likely to stimulate agricultural productivity.

The Cobb–Douglas production function mathematically expresses how inputs (capital and labor) translate into outputs. This production function is based on two assumptions: the first is the law of diminishing returns, and the other is called constant returns to scale. Considering the desire to determine the impact and relationship between the adoption of electrical equipment and cotton

productivity, this study adopted the model of Duke et al. (2016). The productivity function is given by:

$$q = al^{\alpha}k^{\beta} \quad (1)$$

q represents agricultural productivity approximated by agricultural yield per hectare (Q/S); a represents technical progress, l represents the quantity of labor per hectare (L/S), k represents capital per hectare (K/S), α represents the elasticity of labor per hectare, β represents the elasticity of capital per hectare, where S is the sown area. An increase in the quantity of labor (L) while capital (K) constant remains would lead to an increase in agricultural production (Q) and therefore q . An increase in the capital stock while labor remains constant will lead to an increase in the productivity of the agricultural sector. An increase in the level of technology will increase the productivity of cotton. This illustrates that a , k et l have a direct relationship with cotton productivity. Therefore, the implicit form of the model is represented by:

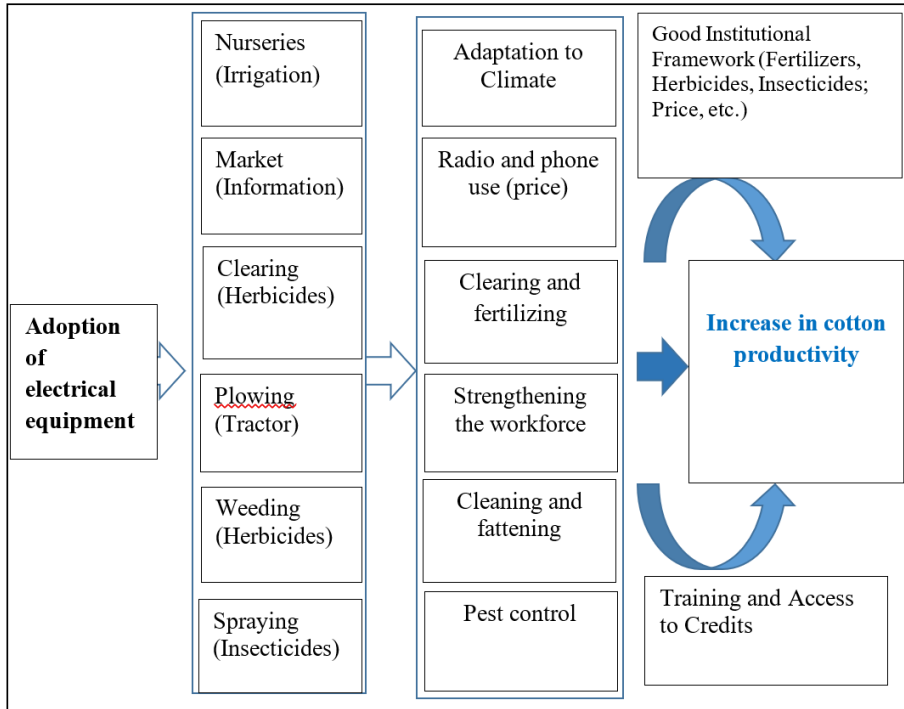
$$Rend = f(M_o, Ad_E, AC) \quad (2)$$

The above equation is rewritten in the linear form adopted from the (nonlinear) Cobb–Douglas model specified as follows:

$$lRend = b_0 + b_1M_o + b_2Ad_E + b_3AC + e \quad (3)$$

where $lRend$ means the logarithm of cotton yield or productivity, M_o represents agricultural labor, Ad_E represents the adoption of electrical equipment, AC represents access to credit. e represents white noise, which captures other explanatory variables not included in the model, b_0 represents the slope, while the coefficients of the model variables are presented by b_1 ; b_2 et b_3 . Figure 1 illustrates the effects of the adoption of electrical equipment on cotton productivity.

Figure 1: Effects of adoption of electrical equipment on cotton productivity



Source: Authors, 2023

6. Methodology

The methodology is divided into two parts, the first of which deals with the method of estimating the determining factors of the adoption of electrical equipment and productivity, then the second part is devoted to the method of evaluating the effect of this adoption on cotton productivity.

The theoretical model and its specification

This section aims to present the analysis tool of our empirical study. Indeed, our regression methodology is based on the econometrics of cross-sectional series. First, we will talk about the approach to analyzing cross-sectional series. Second, we present the source of our data as well as the model variables.

The adoption of electrical equipment can be modeled within a random utility framework. Following Khonje et al. (2018); Zhang et al. (2021), the probability of adopting electrical equipment is a binary choice that leads to a positive difference between the utility of adoption and non-adoption. Thus, the methodology is built around the theory of expected utility maximization. In the context of expected

utility services, farmers make the decision to adopt electrical equipment only when it provides them with an expected utility greater than that expected when they do not adopt it (de Janvry et al. 2010). The difference between adoption (U_{Ai}) and non-adoption utility (U_{Ni}) can be denoted by the payoff DU^* , such that a utility-maximizing farmer, U_i , will choose to adopt power equipment if $DU^* = U_{Ai} - U_{Ni} > 0$. As these utilities are not observable, they can be expressed in terms of the observable elements in the latent variable model DU_i^* such that the probability of this occurring given Z is: $P(DU_i^* > 0) = P(u_i > -\beta Z_i) = 1 - P(u_i < \beta Z_i)$. By symmetry of the density function this is equivalent to $P(DU_i^* > 0) = 1 - F(\beta Z_i)$; $F(\cdot)$ denotes a distribution function, with:

$$DU_i^* = \beta Z_i + u_i \quad \text{and} \quad Ad_{E_i} = \begin{cases} 1 & \text{if } DU_i^* > 0 \\ 0 & \text{if } DU_i^* \leq 0 \end{cases} \quad (4)$$

Where Ad_E is a binary indicator variable equal to 1 if a farmer adopts electrical equipment and zero otherwise; β is a vector of parameters to be estimated; u is the error term, and Z is a matrix of socio-economic determinants of the farmer's status. Equation (4) makes it possible to satisfy the first objective of the study, which is to identify the factors determining the adoption of electrical equipment by the farmer.

To model the effect of this adoption of electrical equipment on cotton productivity, we specify the following implicit model:

$$P_{ij} = f(X_{ij}; D_{ij}) \quad (5)$$

P is productivity, X , a vector of farm level and other characteristics assumed to influence productivity; D is the variable of interest measuring the adoption of electrical equipment. The index i represents a cotton producer, and the index j represents the two treatments (electric energy adopter and non-adoption).

Equation (5) can be modeled with the classic Ordinary Least Squares (OLS) model, where the estimation of the coefficient of D would indicate the effect of the adoption of electrical equipment on cotton productivity in Benin. However, this approach could generate biased estimates because it assumes that the adoption of electrical equipment is exogenously determined when it is potentially endogenous. There is therefore, a problem of selection and endogeneity violating the assumptions of OLS.

Dealing with the problem of endogeneity combined with that of selection bias requires appropriate econometric techniques. Various techniques are used in the literature including the Heckman selection model (Nonvide, 2019; Bacha et al, 2011; Tesfaye et al, 2008), Propensity Score Matching Methods (MASP) (Nkhata et al, 2014; Dillon, 2008), the Instrumental Variables (IV) method (Bezu et al, 2014; Verkaart et al., 2017), and the Regime Change Model (RCM) (Di Falco et al, 2011; Asfaw et al, 2012; Hasebe, 2020). All of these methods are complementary and rely

on assumptions. Jalan and Ravallion (2003) argue that the assumption of selection on observable variables in the MASP approach is no more restrictive than the elimination of weak instrument problems with the Heckman models and those of instrumental variables. The main advantage of the RCM model is its ability to minimize the various biases of impact evaluation (Feder et al, 1990; Mukasa et al, 2017) by allowing joint estimation of the selection and outcome equations through an FIML (*Full Information Maximum Likelihood*) estimator (Asfaw et al, 2012). Another advantage is that the MCR model allows the counterfactual result to be calculated. This motivates the use of a Regime Change Model.

To analyze the effect of the explanatory variables on cotton productivity, the elasticities (e_{ij}) are calculated from the productivity function $P_{ij} = \sum_1^n \beta_{ij} X_{ij}$ as follows:

$$e_{ij} = \frac{\frac{\partial P_{ij}}{DP_{ij}}}{\frac{\partial X_{ij}}{X_{ij}}} = \beta_{ij} X_{ij} \quad (6)$$

To properly interpret this relationship, each member of the equality will be divided by X_{ij} and multiplied by 100 (Houensou et al, 2021), which gives:

$$100 \times \beta_{ij} = \frac{100 \times \frac{\partial P_{ij}}{DP_{ij}}}{\partial X_{ij}} \text{ and finally, we have: } (100 \times \beta_{ij}) \partial X_{ij} = \% \partial P_{ij} \quad (7)$$

From the estimation of the regression model with change of regime, it is possible to know the value of the productivity gain of farmers having adopted electrical equipment, whose formula is that of Guirkinger and Boucher (2008). This is the mathematical expectation of the difference between the predicted value of the productivity of farmers who have adopted electrical equipment and that of their counterfactuals. The higher the expected value of this differential, the greater the gain due to adoption, and the more important it is to work to encourage the adoption of electrical equipment to attract farmers towards progressive mechanization of cotton production. in Benin. By noting GP, the productivity gain and referring to Guirkinger and Boucher (2008) and Mukasa et al. (2017), the productivity gain is deduced by the formula:

$$GP = \frac{E(\hat{P}_1/adop_equip=1) - E(\hat{P}_0/adop_equip=1)}{E(\hat{P}_1/adop_equip=1)} * 100 \quad (8)$$

Study data and variables

The data used in this research are those extracted from the Harmonized Survey on Household Living Conditions (EHCVM) database in West African countries. This survey was part of the Program for Harmonization and Modernization of Surveys on Household Living Conditions (PHMECV) within UEMOA member states. In Benin, the work was carried out by the National Institute of Statistics and Demography

(INStAD), covering the seventy-seven (77) communes. The objective of the survey is to make periodically relevant and reliable information on poverty and household living conditions available to the Government and Technical and Financial Partners. The survey includes two parts: one part among communities and the other among households. The first part is carried out using a focus group whose number of participants varies between 7 and 10 in 746 villages or city districts. The second part covered a sample of 8,012 households, representative at the national, departmental, municipal level, and by area of residence. This sample was drawn following a two-stage sampling plan, with a margin of error of 5%. At the first stage, 750 clusters were drawn from the 920 clusters surveyed during the EMICoV-2015 survey, then at the second stage, 20 households were systematically drawn from each cluster. The sample was drawn by urban/rural stratum at the level of each municipality. In total, 23 strata were thus defined. The sample households were distributed in each department in proportion to their size in terms of the number of households. The main survey took place from October 4 to December 20, 2018, for the first wave, and from April 29 to July 12, 2019, for the second wave, and mobilized 25 work teams composed of three (3) to four (4) investigating agents, each headed by a controller. Four (04) areas of permanent supervision were established and ensured by a mixed team of executives from INStAD, the Ministry of Agriculture, Livestock and Fisheries (MAEP), PAM, and the Ministry of Health. Data was collected using Smartphones and tablets.

After data clearance, it should be noted that the survey was actually carried out in the 77 municipalities with 8,012 households involving 42,343 individuals, including 3,120 agricultural households. Given that this research concerns agricultural households, the variables of the study were based on the 3120, whose informational richness allowed us to take into account all the socio-economic realities of the country, which could satisfy our objectives in terms of evaluation of the effect of the adoption of electrical equipment on cotton productivity in Benin. The model variables and their measurement are summarized in Table 1 below:

Table 1: Definition, measurements and expected signs of variables

Variable labels	Terms	Expected signs
Age	Continuous quantitative variable expressed as number of years of life	+
Age ²	Continuous quantitative variable expressed as number of years of life squared	-
Sex	0- Women 1- Man	+
Instruction	0- Uneducated 1- Educated	+
Phone use	0- Don't use the phone 1- Use of telephone	+
Agricultural labor	Continuous quantitative variable expressed in number of people	+
Agricultural input	Continuous quantitative variable expressed in Kg	+
Financial account	0- Don't have an account 1- Has an account	+
Credit	0- Does not have access to credit 1- Has access to credit	+
Transfers received	0- Did not receive a transfer 1- Received transfer	+
Household shock	0- Did not suffer any shocks 1- Suffered shocks	-
Cultivation area	0- South growing zone 1- Cultivation area Center 2- North growing zone	-

Source: Authors, 2023

The variable of interest among the explanatory variables affecting cotton productivity is the adoption of electrical equipment. Electricity has been shown in the literature as a source of productivity improvement (Daumas and Fomba, 2021). Inventory variables can be considered as indicators of production efficiency. But the increase in volume of cotton production may not lead to high productivity. It is for this reason that productivity is an indicator considered for evaluation in terms of results. There are also observable covariates that could affect the adoption of electrical equipment by farmers, and which influence the latter's productivity. These variables trace the most important factors that push farmers towards electrical equipment and that determine the productivity that we identified in the literature review.

If the theoretical work has focused on the determining factors of the adoption of electrical equipment, the empirical verifications have not remained without a rich contribution around this theme using various variables. Education is a stimulating variable in human productivity. An increase in the level of education contributes to more advanced knowledge of farming techniques and therefore improves productivity. This perception of the variable is shown by the work of Tsomdzo et Kodjo (2021) and Clark and Royer (2013). Similarly, Desai (2000) explains the important effect of education on health outcomes for building human capital and productivity. A positive sign is therefore expected from this variable.

The age of the farmer is a characteristic considered as a quantitative variable; it measures the number of years of life of the farmer. The effect of this variable on productivity is ambiguous in the literature. Thus, we can initially hypothesize that productivity increases with age thanks to acquired experiences. On the other hand, age can have a negative effect on the farmer's physical effort.

Indeed, other socio-demographic variables such as gender and labor force were unanimously agreed in the journal as determining variables of agricultural productivity (Muzazi, 2013; Yabile, 2013). On the other hand, other authors found no effect of gender (sex of household head) on productivity (Arene and Anyaeji, 2010). From these results, there emerges an ambiguity on the sign of the relationship between sex and productivity which must be reprocessed. The labor force is a quantitative variable that refers to the total number of individuals working on the agricultural production farm. Thus, the work of children and women can prove beneficial for increasing household productivity, just like wage labor. On the other hand, the study by Garrett and Ruel (1999) shows that a large size of the workforce is negatively associated with agricultural productivity, taking into account the different related costs.

The growing area is also a key variable for evaluating farmers' productivity due to the diversity of Benin's agroecological zones. It is captured by the three main zones of the country's structure (North, Center, and South). An increase in the rate of urbanization contributes to a reduction in agricultural productivity through limited

access to fertile land. On the other hand, in rural areas towards the north of the country, the availability of large cultivable areas makes it possible to fallow portions for high productivity farming in the future. This reasoning is supported by Bayati et al. (2013) as well as Hao et al. (2018), which justifies the relevance of the variable in our model. A positive sign is therefore expected from the variable.

Possession of information through multiple channels, including telephone, is an essential prerequisite for decision-making (Lambrecht et al. 2014). Telephones are today an important means of access to information and distance training, which impacts the productivity of their users. Thus, the farmer who is well informed about the importance of energy in the production system as well as farming techniques, allocates a significant part of his income to adopt the system and meet the related expenses. A positive sign is therefore expected from the Telephone use variable. Furthermore, the use of inputs is an indicator of the adoption of new production techniques and improvement of agricultural productivity as a whole. Farm inputs appear to provide greater information relevance than farm income because they encompass income but provide an additional signal about productivity, labor intensity, and farm profitability (Zhao, 2014; Brosig et al., 2009).

The various shocks considerably affect the productivity of producers. Beyond natural shocks (floods, droughts, pests) and prices of agricultural products, farmers are subject to individual shocks such as illness, the death of a family member, or loss of employment. In the literature, these shocks are at the same time a cause of a lack of motivation for production and of decline or poor harvest (Asfaw et al, 2019). For the variables linked to the farmer's income (access to credit, possession of a financial account, and transfers received), a range of results showed in various ways the importance of these indicators on agricultural productivity (Chimwamurombe and Mataranyika, 2021; Benton and Bailey, 2019; Muzazi, 2013). The summary of all variables with the expected signs is presented in Table 1 above.

7. Results and Discussions

This part is devoted, on the one hand, to the descriptive analysis of the data and, on the other hand, to the interpretation of the econometric results to make recommendations for economic and social policies.

Descriptive analysis

This presentation allows firstly to focus on the analysis of some categorical variables about adoption and secondly to take stock of the central tendencies and dispersion of the continuous variables of the model through Table 2.

Table 2: Descriptive statistics of some categorical and continuous variables of the model

		Total		Adopters of electrical equipment		No Adopters of electrical equipment	
Effective (%)		3120		1,362 (44.65%)		1,758 (56.35%)	
Categorical variables	Terms	Workforce	%	Workforce	%	Workforce	%
Sex	Femine	440	14.10	179	13.14	261	14.85
	Male	2,680	85.90	1,183	86.86	1,497	85.15
Credit	Yes	287	9.20	153	11.23	134	7.62
	No	2,833	90.80	1,209	88.77	1,624	92.38
Agricultural tools	Yes	254	8.14	119	8.74	135	7.68
	No	2,866	91.86	1,243	91.26	1,623	92.32
Financial account	Yes	812	26.03	497	36.49	315	17.92
	No	2,308	77.97	865	63.51	1,443	82.08
Instruction	Yes	2,862	91.73	1,218	89.43	1,644	93.52
	No	258	8.27	144	10.57	114	6.48
Phone	Yes	2,210	70.83	1,073	78.78	1,137	64.68
	No	910	29.17	289	21.22	621	35.32
Continuous variables	Ttest	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
Cotton productivity (Kg/ha)+	1,323 *	1,948	17,422	2,317	21,938	1,435	7,536
Workforce	- 2.36***	2.43	7.82	2.81	8.21	2.14	7.49
Age	-1.68*	47.75	13.89	48.23	14.21	47.35	13.63

+ in thousands of Kg/ha

***p<0.01; **p<0.05

Source: Calculations based on EHCVM data, 2019

Analysis of the first part of Table 2 shows that the adoption of electrical equipment is problematic in Benin. Out of 3,120 cotton-producing agricultural households in the study base, only 44.65% have adopted electrical equipment.

Furthermore, 85.90% of cotton producers are men. Most of them have a low rate of access to credit (9.20%) with low ownership of agricultural tools (8.14%). They have low possession of financial accounts (26.03%) with massive education (91.73%), and high use of telephones (70.83%). These indicators are indicated differently depending on the adoption status of electrical equipment. For the group of producers who have adopted electrical equipment, men are slightly more represented (86.86%) compared to the group of non-adopters of electrical equipment. This result testifies to the reality of the country in the production of cotton, according to which men would make large crops requiring the support of modern tools, especially with energy requirements. Access to credit follows the same trends, with a higher rate (11.23%) in the group of producers who have adopted electrical equipment compared to 7.62% of farmers who have not adopted electrical equipment. For the possession of agricultural tools, only 8.74% of producers who have adopted electrical equipment own agricultural production tools. This rate is lower (7.68%) for all producers not adopting electrical equipment. Owning equipment would require electrical energy to operate it.

For electrical equipment adopter producers, financial account ownership is quite high (36.49%) compared to the account ownership rate of non-adopters (17.92%). This would provide for an allocation of funds from the accounts for a renovation of the production system by involving electrical equipment. In the cotton production system, several actors are involved, and particularly would be educated. Table 2 confirms this assertion: 89.43% are educated among producers who have adopted electrical equipment. The non-adoption group has a higher education rate of 93.52%. Basic knowledge in schools and parallel training places is recognized by all economic players as a necessity. Stays in training rooms would be an important factor in improving agricultural productivity. The development of new information and communication technologies would have enabled telephone inclusion in Benin. This is justified by the high rate of telephone use in both groups. This rate represents, respectively, according to their importance, 78.78% and 64.68%.

The analysis of the second part of Table 2 shows a strong dispersion around the mean (high standard deviations and even higher than the means (except age) of all the variables. This deviation would be justified by an unequal endowment of resources (labor) and productivity of cotton producers in Benin. This research is necessary to highlight the reasons for this disparity in order to raise awareness for a common-sense agricultural policy orientation. The characteristics of the trends, the central values of these variables are also presented in the same table.

It appears from this part of the said table that, on average, cotton productivity is estimated at 2317 kg/ha for adopters of electrical equipment and at 1435 kg/ha for

non-adopters. These statistics indicate that the adoption of electrical equipment in the cotton production process would increase its productivity. The use of pesticides and herbicides through electrical devices accelerated the production process. Sowing at good dates of the cotton campaign ensures growth and good flowering with a good treatment system using electrical spraying devices. Thus, a good harvest is observed at the cotton harvest. The workforce is, on average, 2.81 people for producers who have adopted electrical equipment and 2.14 people for non-adopters. This indicates that labor would boost the adoption of electrical equipment in the cotton production process. In agricultural production areas, having a large number of people in the household and outside the household available constitutes a labor supply to support production. This motivates the extension of cultivated areas and therefore calls for a growing need for modern energy-consuming equipment that can help production. Thus, this result would reflect the additional need for the adoption of electrical equipment in order to increase cotton productivity in Benin.

The average age of farmers, estimated at 47.75 years, shows that they are generally young to meet the physical needs required by the sector. Table 2 indicates that the youngest adopt less electrical equipment in the group of non-adopters of electrical equipment (47.35 years on average) than in the group of adopters of electrical equipment (48.23 years on average). These results demonstrate the fact that cotton production requires physical efforts that young people have relative to older people. Thus, these young people, instead of adopting energy equipment to cope with production, would concentrate on their physical effort. The finding is the opposite among relatively older producers who are accompanied by these modern production methods, requiring a low amount of physical effort. From these analyses, age would be considered a determining factor in the adoption of electrical equipment in cotton production in Benin.

Econometric analysis

Table 3 presents the results of the maximum likelihood estimation of the Regime Switch Model. The results presented in column (1) of Table 3 provide the driving forces behind the adoption of electrical equipment by cotton producers in Benin.

The coefficients associated with the variables education, telephone use, financial account, inputs, transfers received, household shock, and cultivation area are significant. Educated cotton farmers are less likely to adopt electrical equipment than uneducated cotton farmers. An educated producer is 25.7% less likely to adopt electrical equipment in their production system than one with no level of education. We can therefore understand that education has a reassuring effect on the adoption of electrical equipment by cotton producers. The educated farmer has a mastery of cultivation techniques and sees no need to adopt electrical equipment before increasing his productivity. This result is contrary to those of the work of Ahn et al. (2013), who concluded that limited knowledge and skills are the

main barriers to the adoption of energy sources. Likewise, these results invalidate those from the work of Tsomdzo et al. (2021) and Clark and Royer (2013).

The use of mobile phones by the cotton producer makes him suitable for the adoption of electrical equipment for production. The cotton producer who owns telephones increases his chance of adopting electrical equipment by 32.3%. This result could be explained by the fact that the possession of information by the cotton producer on cultivation techniques, the price of goods and services and opportunities linked to other sectors, allows him to properly adjust the level of its production for better productivity. This result is consistent with those of the work of Hwang and Tang (2012) then Hwang and Ng (2013), who demonstrated in the same way that the lack of information and communication of market actors on demand and supply are factors that limit the adoption of modern technologies including electrical energy. Similarly, Lambrecht et al. (2014) show that the possession of information through telephones is prior and essential to deciding to adopt an innovation.

Agricultural input is a factor determining the adoption of electrical equipment in the cotton production system by cotton producers in Benin. If the quantity of input used increases by one kilogram, the household is 0.0003% less likely to adopt electrical equipment in cotton production. The use of inputs is considered a substitute for the adoption of electrical equipment. These results are contrary to those of the study by Garrett and Ruel (1999).

Having a financial account, whether bank, post office, microfinance institution or mobile money, increases the chance of adopting electrical equipment by 46.6%. This could be explained by the fact that the account allows the cotton producer to build up financial reserves during the harvest period and product sales to cope with lean periods. These reserves constitute necessary means for the adoption of electrical equipment and many other expenses linked to the opening of the cotton production season. This result is reassured by those of Ahn et al. (2013), who identified cost as a determinant of energy adoption, but also by those of Chan et al. (2017), finding resistance to adoption due to higher electrical energy costs. The transfers received are also sources of income, which make it possible for cotton-producing farmers to adopt electrical equipment. As a subscription to the electricity network requires an initial investment, these transfers constitute an important lever supporting farmers in the adoption of electrical equipment. The payment of bills is relieved by these various transfers. The producer who received the transfer has a 17.2% greater chance of adopting electrical equipment in his production system through the purchase of production processing equipment. These results are consistent with the work of Muzazi (2013), who affirms that the transfers received are transitional income that supports producers in the modernization of their production systems.

Regarding the shock, our results indicate a positive effect of 14.2% on the adoption of electrical equipment by cotton farmers. Producers facing shocks are more likely to adopt electrical equipment to resist the negative effects of the shock. These results, which meet our expectations, confirm the work of Asfaw et al. (2019), which demonstrates that shocks are at the same time a cause of a lack of motivation for production and of a drop or poor harvest. The cultivation area is an instrument of the estimation model, which affects the decision to adopt electrical equipment and impacts cotton productivity. Cotton farmers moving from the south to the north have a motivation to adopt electrical equipment. Indeed, there is a large cultivable area in the northern zone of the country that grows a large area of cotton, which requires adequate equipment for the maintenance of the crop.

The correlation between the adoption of electrical equipment and agricultural productivity outcomes is theoretically complex, and there are other empirical pitfalls regarding the problem of assessing the effects of an economic indicator on this outcome variable. Thus, before evaluating the effect of the adoption of electrical equipment on cotton productivity, we first estimated the factors explaining cotton productivity in each category of farmers according to whether they adopt electrical equipment and whether they do not adopt it. The results are presented in Columns (2) and (3) of Table 3. These two columns present the productivity function for cotton farmers who have adopted electrical equipment (2) and who have not adopted electrical equipment (3).

The explanatory factors for cotton productivity among adopters and not of electrical equipment (Columns 2 and 3 of Table 3) are as follows: gender (sex), education, use of telephone, financial account, and transfers received. These results show that male adopters are on average 48% more likely to increase their cotton productivity than female producers who have adopted electrical equipment. Furthermore, male producers who have not adopted electrical equipment are 48.2% more likely to increase their agricultural productivity than female producers who have not adopted electrical equipment. Indeed, agricultural activity as a whole requires intense physical efforts that men have compared to women. Further, cotton production requires in its process, activities specific to men such as spraying. At this level, women need help from men to accomplish this task. This can slow down the process and therefore negatively impact their productivity. These results are consistent with the work of Muzazi (2013).

Table 3: Econometric results of the relationship between the adoption of electrical equipment and cotton productivity in Benin

Dependent variable: Cotton Productivity	Determinants of adoption of electrical equipment (1)	Cotton Productivity	
		Adopters (2)	Non-Adopters (3)
Age	-0.006(0.01)	-0.009 (0.03)	-0.018 (0.22)
Age ²	0.0001 (8.92e-05)	-0.001 (0.0001)	-2.49e-04 (2.1e-04)
Gender (male)	-0.08 (0.07)	0.48 (0.27)*	0.4 (0.15)***
Instruction	-0.257 (0.08)***	0.85 (0.31)**	0.409 (0.23)
Phone use	0.323 (0.05)***	-0.87 (0.22)***	-0.293 (0.12)**
Workforce	0.002 (0.01)	0.01 (0.01)	0.020 (0.004)***
Inputs	-2.3e-06 (1.3e-6)*	1.9e-05 (4.3e-05)	1.6th-06 (4.2nd-07)***
Financial account	0.466 (0.05)***	1.23 (0.21)*	-0.535 (0.15)***
Credit	0.043 (0.07)	0.452 (0.29)	-0.188 (0.23)
Transfers received	0.172 (0.05)**	-0.816 (0.22)***	-0.570 (0.15)
Household shock	0.142 (0.07)*	0.314 (0.29)	-0.145 (0.17)
Cultivation Zone: reference (North Zone)			
Cultivation area	0.117 (0.02)***	-	-
Constant	-0.577 (0.29)**	9.796 (1.05)**	4.774 (0.67)***
Comments	2963	2963	2963
Rho_0		-0.376 (0.49)***	
Rho_1		-2.147 (0.07)***	
Log likelihood: -8518.9086; Wald chi2 (11) = 117.98; Prob > chi2 = 0.0000			
Wald test of indep, eqns,: chi2 = 961.34; Prob > chi2 = 0.0000			

***p<0.01, **p<0.05, *p<0.1. Robust standard errors in parentheses

Source: Results from HECVM data, 2019

Subsequently, education positively affects cotton productivity both at the level of producers adopting electrical equipment and at the level of non-adopters. Thus, an educated producer has 85% more chance of increasing his productivity when he has adopted electrical equipment. In the group of non-adopters, the educated have 40.9% more chance of increasing their cotton productivity. As found in the work of Yabile (2013) and Simikiwe et al, (2014), this is because education improves the capacity of cotton producers to adopt good agronomic practices reinforced by electrical equipment and therefore to increase productivity. Telephone use negatively and significantly affects the productivity of producers who have adopted electrical equipment. Compared to a producer not using a telephone, the cotton productivity of a telephone user drops by 87.4% in the adopter group. In reference to non-adopters, this productivity drops by 29.3%. Indeed, telephone use plays an important role in the life of cotton producers in the search for commercial opportunities for agricultural products. At the same time as it is a communication tool; the telephone constitutes radio for cotton producers to obtain information on the market in general and to train on new products that can be traded, leaving the concentration on the agricultural production (Hwang and Tang, 2012; Hwang and Ng, 2013).

In the same sense, the possession of a financial account is a determining factor in cotton productivity in Benin. A cotton producer with a financial account in the group of adopters and non-adopters of electrical equipment has respectively 123.5% and 53.5% less chance of increasing his cotton productivity than one without an account financial. The account is a catalyst for access to credit, ensuring the orientation of cotton farmers towards other market opportunities. The account is a source of income to cope with shocks linked to the lean period and many other current expenses, ensuring an orientation towards trade. The transfers received are also factors reducing agricultural productivity. A cotton producer who received a transfer lowered his productivity by 81.6% in the group of adopters of electrical equipment in his mode of production. These results confirm the work of Kumari and Garg (2023), which shows that credit and transfers via financial accounts are very important factors in economies and in their diversification. In contrast, the results invalidate the work of Lin et al. (2019), which shows that access to credit and transfers moderated by current financial accounts is of vital importance, as it can financially facilitate farmers' investment in the agricultural sector as a whole.

Labor ensures cotton productivity in Benin, but the effect is only significant in the group of producers who have not adopted electrical equipment. In this group, productivity increases by 2.01% when the workforce increases by one member. Considered as a labor factor, the available workforce ensures the production, especially of cotton in Benin. The availability of labor allows mass production and ensures the maintenance of sown areas. In the same sense, agricultural input is a factor stimulating the cotton productivity of farmers who have not adopted electrical equipment. The use of input by a producer has a positive and significant

effect on their productivity. This effect is a 0.0002% increase in productivity in the group of non-adopters of electrical equipment. In the group of adopters, the effect is similarly positive but not significant. These results are consistent with the work of Zhao (2014) and Brosig et al. (2009), who for them inputs provide high relevance of information and an additional signal on productivity, labor intensity, and profitability of the farm.

To understand the effect of the adoption of electrical equipment on cotton productivity, we examined the differential effect of adoption on productivity. Table 4 below presents the expected productivities under the counterfactual analysis for adopters and non-adopters. Cases (a) and (b) correspond to the expected productivity, i.e. on average 1099 kg/ha for adopters and 826 kg/ha for non-adopters. An analysis of the t-test ($t = -7.124$) between the two groups showed that cotton producers who adopted electrical equipment had significantly higher productivity. The adoption of electrical equipment by cotton producers allows them to focus on the profitability of devices, leading to better productivity. These results confirm those of the previous works listed above. The same Table 4 presents the effects of the treatment on the two groups of cotton producers. In the counterfactual case (c), productivity would be lower, going from 1099 to 612 kg/ha if cotton producers who had adopted electrical equipment had not done so. In the opposite case, if cotton producers who had not adopted electrical equipment had done so (case (d)), they would have a productivity of 3328 kg/ha, or an additional 2502 kg/ha. These results show that the adoption of electrical equipment actually has a positive effect on productivity, better cotton productivity in Benin.

From this same Table 4, we calculate the productivity gain GP through Equation (8).

$$GP = \frac{a - c}{a} * 100$$

$$GD = \frac{1099 - 612}{1099} * 100$$

$$GD = 44,31\%$$

Thus, overall, the adoption of electrical equipment in the current cotton production system has a productivity gain of 44.31%. This result aligns with previous work that has been done on businesses, showing the importance of electrical energy in industrial productivity.

Table 4: Average expected returns for cotton producers

Subsample	Decision phase		Treatment effects
	Adopting	Not Adopting	
Adopting	a) 1099 (0.037)	c) 612 (0.114)	TT = 487***
Not Adopting	d) 3328 (0.032)	b) 826 (0.111)	TU = 2502***
Heterogeneity effects	BH ₁ = -2229***	BH ₂ = -214 ***	TH = -2015***

*** p<0.01, Robust standard errors in parentheses

Source: Authors' calculations, 2023

7. Conclusion and Policy Recommendation

The objective of this research was to analyze the effects of the adoption of electrical equipment on cotton productivity in Benin. To achieve this objective, the Regime Change Model was used to estimate both the determining factors of the adoption of electrical equipment and the effects of this adoption on cotton productivity in Benin based on data from the base of the Harmonized Survey on Household Living Conditions in Benin (EHCVM, 2019). This model controls for biases due to observable and unobservable factors. It indicates through its results that the variables age, education, possession of a mobile phone, household size, financial account, and transfers received positively determine the adoption of electrical equipment by cotton producers in their production system. The results also revealed that the adoption of electrical equipment positively affects cotton productivity in Benin. The following sociodemographic variables have both a positive effect on the cotton productivity of adopters and non-adopters. These are gender, cell phone use, and financial account ownership. Education and transfers received are additional variables that significantly affect the productivity of cotton producers who have adopted electrical equipment. However, among non-adopters of electrical equipment, household size and ownership of agricultural equipment are the additional factors that have an effect on their productivity. Further, and more precisely, the productivity gain for a producer adopting electrical equipment is calculated and estimated at 44.31%. This gain in productivity suggests that cotton producers who have not adopted electrical equipment do so in the hope, all things being equal, of an increase in their productivity on average of 44.31% compared to their current level of productivity.

The economic policy implications of this study are the increase in the coverage rate of electrical energy, the orientation of cotton farmers towards equipment using electrical energy, and the popularization of their adoption, especially in areas of intense production for increasing cotton productivity in Benin.

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