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Evaluating the impact of improved technology adoption in traditional poultry farming on potential outcomes of farmers: evidence from rural Togo

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ABSTRACT

Social programs are designed to reach beneficiaries and achieve expected objectives. There is a need to understand whether development programs work and their level of impact on the beneficiaries involved. Along these lines, the objective of this study is to evaluate the impact of Improved Technology adoption in Traditional Poultry Farming (ITTPF) on farmers' potential outcomes in Togo. Baseline and follow-up data were collected from 400 farmers and analyzed using difference-in-differences models. The study reveals that five years after the implementation of the program, the annual gross profit increased on average by US\$ 1294 for each program participant. The results of the heterogeneous impacts assessment indicate that participating in the program is a necessary condition for ITTPF adoption, but not sufficient for profit optimization. Overall, the program has a positive and significant impact on the potential outcomes of farmers in Togo. The government in its agricultural policy should mobilize more resources to enable considerably more farmers to adopt improved agricultural technologies. In addition, agricultural policymakers should implement the instruments of the chain planning, programming, budgeting, execution, monitoring and evaluation of all agricultural development programs and projects to make progressive adjustments for optimal results achievement and sustainable agricultural development.

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1. Introduction

The agricultural sector is at the heart of the economy of developing countries. It generates a large share of the gross domestic product (GDP) and employs a significant proportion of the active population. It is an important source of foreign exchange,

produces the most basic foodstuffs and is the only source of livelihood and income for more than half of the population of developing countries (OECD/FAO, 2023; Soviadan et al., 2022, 2023).

The poultry sector is an agricultural sub-sector that continues to grow in many parts of the world. The increasing purchasing power of the population

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and urbanization have been powerful drivers of this growth. Therefore, poultry production has become highly specialized and increasingly productive and hence needs to be managed by specialists (Food and Agriculture Organization of the United Nations [FAO], 2015).

In addition, the development and transfer of technologies and farming techniques increased the efficiency of poultry production. This has led modern poultry farms to grow rapidly in size, concentrate near sources of inputs or output markets and opt for vertical integration (Ao et al., 2021; Chen et al., 2024; Mahanty et al., 2023).

This structural reform is particularly reflected in the evolution of contract farming in the breeding of layers and broilers, which allows farmers with medium-sized units to access advanced technology with a relatively low initial investment (FAO, 2015).

Traditional poultry farming is defined as small-scale, household-level poultry production using family labor and, to the greatest extent possible, locally available food supplies (McCloughlin et al., 2024; Wong et al., 2017). It is the most common type of breeding practiced by smallholder farmers in Sub-Saharan Africa (SSA) due to low entry barriers. It plays a crucial role in rural areas of developing countries in sustaining livelihoods, supplying poultry products in rural, suburban and urban areas and representing important support (such as health care for family members, school fees for children, cultural events, rituals, etc.) for the most vulnerable groups (FAO, 2014). As long as poverty persists in developing countries, traditional poultry farming will continue to provide opportunities for high-quality income generation and nutrition for the human population (FAO, 2015).

The modern large- and medium-sized poultry production system supplies integrated marketing chains while the free-range, low-income, family-scale poultry production system is supplying local or niche markets.

Traditional poultry rearing is the most commonly used method of poultry production in Togo because it is less expensive than modern commercial poultry farming or other types of livestock production. It is well-established among smallholders in rural Togo due to low entry barriers and is considered an economic activity that could be easily accessed even by the most vulnerable social strata of the population (eg low-income, landless and female farmers) (FAO, 2014). However, this sector is characterized by low productivity because its production potential is inherently low combined with poor environmental

and feeding conditions. Losses are usually due to disappearances, theft and slaughter because of the extensive nature of this type of breeding. High mortality and slow growth of poultry are the major constraints to production. The most common mortality causes are diseases, predation, external parasites and accidents. The majority of constraints in traditional poultry farming are related to farm management techniques.

In this context, and intending to make traditional poultry farming more productive and efficient to enhance food security, diversify income sources and thus strengthen the resilience of farmers for wealth creation and poverty alleviation, the introduction of ITTPF becomes crucial. The improved traditional poultry farming differs from free-range traditional poultry rearing in several respects. The improved poultry farming is semi-intensive as the poultry birds are raised in an enclosure with a well-built habitat called a semi-modern or improved traditional poultry housing. In addition, the bird species and feed quality are improved, the breeding equipment is semi-modern and the hygiene and health care are periodic (FAO, 2014, 2015; Soviadan et al., 2022, 2023; Yadav et al., 2013).

Since 2014, through the National Program of Agricultural Investment for Food and Nutritional Security (PNIASAN), and the Agricultural Sector Support Project (PASA), the government in Togo with the help from the FAO and the financial support from the World Bank has been assisting smallholder farmers in rural areas with the adoption of Improved Technology in Traditional Poultry Farming (ITTPF) to create wealth, improve food security and alleviate poverty (Soviadan et al., 2022, 2023). The ITTPF is a commercial type of traditional poultry farming that differs from free-range traditional poultry rearing in terms of improvements in farm management, farm equipment, poultry housing, poultry feed and disease control. Despite the measures taken by the government to make participation in the program more accessible to farmers, only 86 were able to be enrolled in it in 2014. Since not all farmers participated in the program, there is a need to categorize them into two groups, that is, the treated group (program beneficiaries) and the untreated group (program non-beneficiaries).

Several previous studies referred to any intervention program as 'treatment' (Alem & Ruhinduka, 2020; Carter et al., 2019; Cole & Fernando, 2021; Gao et al., 2020; Rubin, 1974). The term 'treatment' refers to early work in the medical field that focused on determining the efficacy of treatments. Although it is not

the most appropriate term, it is used in econometrics to describe public intervention, subsidy policy, social assistance program or implementation of a development program that is being evaluated. Rubin's (1974) counterfactual framework, which has been adopted by many researchers in statistics and econometrics, including Rosenbaum and Rubin (1983), Heckman (1992, 1997), Imbens and Angrist (1994), Angrist et al. (1996), Heckman et al. (1997), allows for the definition of various treatment effects that may be of interest. Once the treatment effect is defined, one can study ways to consistently estimate this effect (Wooldridge, 2010). The literature on treatment effects begins with a counterfactual, where each individual in the population has an outcome with and without treatment. To ensure an unbiased treatment effect evaluation, it is essential to identify the type of treatment based on the stochastic and behavioral attributes of the population. Therefore, to apply the most appropriate impact evaluation method to an intervention program, there is a need to compare the socioeconomic characteristics of beneficiaries and non-beneficiaries of this program before its implementation. The balanced socioeconomic characteristics for both treated and untreated groups should, therefore, be used as control variables for the impact evaluation analysis of the program. Furthermore, a development program is only relevant if the potential outcomes of beneficiaries differ significantly from those of non-beneficiaries after the program's implementation. Before conducting the impact evaluation analysis, it is critical to confirm the existence of a significant difference in the potential outcomes of the two groups (treated and untreated) in the population. Note that, since the introduction and implementation of ITTPF, there were no impact assessment studies to verify if the ITTPF is delivering on its intended promise of boosting livelihoods and reducing poverty. To the best of our knowledge, this is the first attempt to fill knowledge gaps in evaluating the impact of ITTPF adoption on farmers' potential outcomes in Togo.

The rest of this article is organized as follows. [Section 2](#) highlights the implementation of ITTPF in Togo. [Section 3](#) covers materials and methods. Research findings are presented and discussed in [Section 4](#). The conclusion and policy recommendations are outlined in [Section 5](#).

2. Poultry value chain in Togo

Since the Maputo Commitments¹ in 2003 (Benin & Yu, 2012), the Comprehensive Africa Agriculture

Development Program (CAADP) has been at the heart of many African governments' efforts to accelerate growth and reduce poverty and hunger in African countries through the African Union (AU) and the New Partnership for Africa's Development (NEPAD). The Economic Community of West African States' Regional Agricultural Policy (ECOWAS/ECOWAP) was developed as a result of CAADP implementation in 2005 (Kolavalli et al., 2012). Since 2010, Togo has been implementing the PNIASAN with assistance from the FAO and the World Bank, as part of its agricultural policy for sustainable development (Soviadan et al., 2022, 2023). The objective of PNIASAN was to improve food and nutritional security, increase farmers' income and contribute to improving trade balance and rural people's living conditions through sustainable development, with special attention paid to the poorest and most vulnerable groups (ROPPA, 2013; World-Bank, 2017). PNIASAN comprised five projects, including the PASA. The main goal of PASA was to increase the productivity and/or competitiveness of strategic food crops, export crops and livestock farming and to promote an environment conducive to sustainable agricultural development.

In this regard, a sub-component of PASA was aimed at reviving the livestock sub-sector, the specific objective of which was to provide short-term emergency assistance to rehabilitate poultry and small ruminant production, assist small livestock farmers to develop and improve livestock farming in rural areas for wealth creation, food security and poverty reduction (Soviadan et al., 2022, 2023). The government, through this sub-component of PASA, has made available to all farmers in rural areas a technical package to facilitate the adoption of ITTPF. This technical package includes the construction of semi-modern poultry houses (improved poultry farms), the provision of technical poultry rearing equipment, training on the composition of balanced and quality feed at lower cost, prophylaxis, vaccination of poultry, cleaning and hygiene of poultry farms, health care, etc. The cost (per farmer) of the technical package is about US\$ 6364. Through PASA, the government, with help from FAO and financial support from the World Bank, subsidized the cost of the acquisition of the technical package at the level of 90%, while farmers were required to contribute the remaining 10%, which is about US\$ 636 per farmer. This counterpart or individual contribution from farmers interested in PASA could be paid in cash or in kind. Most farmers opt for in-kind contributions, through

land used as a site for the implementation of semi-intensive or improved poultry farms. Farmers who were aware of the benefits of PASA in terms of food security, wealth creation and poverty alleviation in rural areas, but who lacked both financial capacity and land to cover their 10% counterpart, have taken out loans from financial institutions to participate in PASA for the adoption of ITTPF (Soviadan et al., 2022, 2023).

3. Materials and methods

3.1. Agricultural technological change

Since strict geographical limits exist on horizontal expansion (known as extensive margin growth), agricultural production growth will need to come mainly from vertical expansion (known as intensive margin growth) (Besedeš & Prusa, 2011; Black, 1929; Chaney, 2008; Mamo et al., 2019). Agricultural growth concerns have focused on technological and institutional innovations that can increase total factor productivity (TFP) (Bachewe et al., 2018; Dias Avila & Evenson, 2010; El Ghak et al., 2020; FAO, 2017; Fuglie et al., 2020; Gong, 2020). For agricultural technology to be used and have an impact on agricultural production growth, it must meet three requirements: generation, adoption and diffusion (De Janvry, 1973; Foster & Rosenzweig, 1995, 2010; Gallardo & Sauer, 2018; Gollin et al., 2005; Magruder, 2018).

The technology must be generated, socially profitable and locally available. It should be adopted by individual farmers for whom it is appropriate. It has to diffuse among farmers, generating partial and general equilibrium effects on prices and on the welfare of both producers and consumers (Feder et al., 1985; Feder & Umali, 1993; Lee, 2005). The agricultural technology may consist of an overall change in the agricultural production function, as seen in the Solow model, where a gain in TFP will result in an increase in output for a certain combination of inputs, or an equivalent reduction of input costs to achieve a given output level (Bachewe et al., 2018; Evenson & Fuglie, 2010). More particularly, though, the technology is intended to achieve specific gains that will be of interest to the adopter with various advantages or costs to others as a consequence of adoption (Balakrishnan et al., 1996; Kuan & Chau, 2001; Robertson & Gatignon, 1986). Once the technology is available, it has to be adopted by farmers to have an impact on agricultural production and productivity.

3.2. Econometric methods of impact evaluation

The real hurdle of an impact assessment study is determining what might have occurred to beneficiaries without the implementation of the program (Rubin, 1974). In the absence of any program or project, a beneficiary's potential outcome would be its counterfactual. The counterfactual outcome framework can be applied in situations where each farmer in the population comes up with two possible potential outcomes, such as adopting or not adopting ITTPF. A program intervention, such as the implementation of ITTPF, aims to strengthen food security, increases income levels and improves the well-being of the targeted beneficiaries. Note that it is not possible to draw any conclusions about the impact of the program on beneficiaries' potential outcomes based on a single observation after the treatment. The problem with assessment is that, while the impact evaluation of the program can only be truly assessed by comparing actual and counterfactual potential outcomes, the counterfactual cannot be observed (Heckman & Vytlacil, 2001; Khandker et al., 2009). If there is no information on the counterfactual, then the most appropriate option is to compare the potential results of treated participants or individuals to those of comparison or an untreated group that has not received treatment (Rubin, 1974). By doing this, one tries to select a subpopulation or comparison group that is highly comparable to the treated group, in such a way that those being treated would have had potential results similar to those in the untreated group if treatment had not been administered. Finding a good comparison group is critical to a successful impact evaluation. Equation (1) illustrates the fundamental evaluation problem of comparing potential outcomes Y across treated and untreated individuals i (Heckman & Vytlacil, 2001, 2005; Khandker et al., 2009)

$$Y_i = \alpha X_i + \beta T_i + \varepsilon_i \quad (1)$$

T is a dichotomous variable which is 1 for participants in the program or 0 otherwise; X represents a set of observable socioeconomic characteristics specific to individual i ; and ε is a stochastic error term representing non-observed factors affecting Y . Equation (1) captures a standard approach in impact assessment estimating the program's direct effect (T) on potential outcomes (Y). The issue with estimating Equation (1) is that the assignment into the treatment might not always be random due to the intentional placement of the program as well as self-selection in the program (Khandker et al., 2009). In other words, programs are

located based on the needs of populations and individuals, who then self-select given program set-up as well as placement. The auto-selection process could be associated with observed characteristics as well as factors that have not been observed, or both (Rosenbaum & Rubin, 1983). When unobserved variables are integrated, the stochastic error term (ε) in estimated Equation (1) will include variables that are also interrelated with the dichotomous treatment variable (T). In Equation (1), such unobservable factors cannot be measured and thus cannot be accounted for, resulting in non-observed selection bias. In other words, if the covariance between the treatment (T) and the stochastic error term (ε) is different from zero, that is, $Cov(T, \varepsilon) \neq 0$, then this violates an important ordinary least squares (OLS) assumption, necessary to obtain unbiased estimates. As a result, the correlation over time between (T) and (ε) biases other estimates in Equation (1), particularly the estimate of (β), which is the causal effect of the treatment on potential outcomes (Y). The main challenge of a robust impact evaluation study is therefore to develop techniques and methods for eliminating or taking into account the selection bias (Khandker et al., 2009; Soviadan et al., 2022).

Several different methods can be used in impact evaluation theory to address the fundamental question of the missing counterfactual. Each of these methods carries its assumptions about the nature of potential selection bias in program targeting and participation, and the assumptions are crucial to developing the appropriate model to determine program impacts (Heckman & Vytlačil, 2001, 2005; Khandker et al., 2009). Because in our study, the data before and after the implementation of the ITTPF are available for both treated and untreated groups of farmers, the double differences or difference-in-differences (DD) method under the parallel-trend assumption is the appropriate impact assessment technique to evaluate the impact of ITTPF adoption on the potential outcomes of farmers in Togo. DD methods assume that unobserved selection is present and that it is time-invariant. The treatment effect is assessed by taking the difference in potential outcomes across treated and untreated groups of farmers before and after the introduction and implementation of ITTPF.

3.3. Empirical specifications

3.3.1. DD methods of estimating

$$Y_{it} = \beta_0 + \beta_1 t + \beta_2 T_i + \beta_3 T_i t + \mu_{it} \quad (2)$$

where Y_{it} is the potential outcome; β_3 is the estimator of the DD, the coefficient of the interaction term between time t and the treatment variable T_i ; β_2 is the fixed difference between the mean outcome values for the treated and untreated groups in the absence of any treatment; β_1 is the measurement of changes in results' mean values in the absence of any treatment; β_0 is the constant; and μ_{it} is the stochastic error term. The variables t and T_i are included separately to take into account the potential effect of the passage of time and an effect from being included in the treated group (a priori, not zero if the treatment is not random).

The estimates of the coefficients in this regression lead to the following results:

$$Y_{it} = \beta_0 + \beta_1 t + \beta_2 T_i + \beta_3 T_i t + \mu_{it}$$

$$DD = \left[E(Y_{i1} - Y_{i0} | T_i = 1) \right] - \left[E(Y_{i1} - Y_{i0} | T_i = 0) \right] \quad (3)$$

$$DD = \left[\begin{array}{c} [(\beta_0 + \beta_1 + \beta_2 + \beta_3)] \\ -(\beta_0 + \beta_2) \end{array} \right] - \left[(\beta_0 + \beta_1) - (\beta_0) \right] \quad (4)$$

$$DD = [\beta_3 + \beta_1] - [\beta_1] \quad (5)$$

$$DD = \beta_3$$

The DD equation can also be rewritten as follows:

$$Y_{it} = \beta_0 + \beta_1 \text{time} + \beta_2 \text{Treatment} + \beta_3 (\text{time} * \text{Treatment}) + \mu_{it} \quad (6)$$

$\text{time} = 0$ before the treatment and $\text{time} = 1$ after the treatment

$\text{Treatment} = 0$ for the untreated group and $\text{Treatment} = 1$ for the treated group

The DD estimate is obtained following these iterations:

$$E(Y_{it} | \text{time} = 1, \text{Treatment} = 1) = \beta_0 + \beta_1 + \beta_2 + \beta_3 \quad (7)$$

$$E(Y_{it} | \text{time} = 0, \text{Treatment} = 1) = \beta_0 + \beta_2 \quad (8)$$

$$E(Y_{it} | \text{time} = 1, \text{Treatment} = 0) = \beta_0 + \beta_1 \quad (9)$$

$$E(Y_{it} | \text{time} = 0, \text{Treatment} = 0) = \beta_0 \quad (10)$$

Now define:

$$E(Y_{it} | time = 1, Treatment = 1) - E(Y_{it} | time = 0, treatment = 1) = D_1 = \beta_1 + \beta_3 \quad (11)$$

$$E(Y_{it} | time = 1, Treatment = 0) - E(Y_{it} | time = 0, treatment = 0) = D_2 = \beta_1 \quad (12)$$

Therefore

$$DD = D_1 - D_2 = \beta_3 \quad (13)$$

3.3.2. Parallel trends assumption

β_3 is the DD estimate and thus the real impact of improved technology adoption in traditional poultry farming on the potential outcomes of farmers in Togo. β_3 concerns production, productivity, turnover and profit.² The DD method is based on the parallel-trends assumption which states that endogeneity and unobserved heterogeneity in program participation may be present but that such factors are time-invariant. This impact evaluation study is therefore based on the following requirements: (i) the selection bias is invariant over time that is changes in potential outcome variables due to the intervention are not a function of the initial conditions that influenced program participation, (ii) there were no other programs introduced concurrently, and no time-persistent shocks and (iii) the potential outcomes would not have been different over time in the treated group compared to the untreated group if the program had not been introduced (please refer to the graphical results of the parallel trends assumptions tests in the appendix).

3.4. Study area and data collection

This study adopted a farm household survey design. The survey was conducted between July and October 2020 in the five regions of Togo (see Figure 1). Documentation and field visits allowed us to identify the different districts and localities of the five major rural areas involved in this investigation. The target population size represented the total number of farmers in Togo. The sample size for this study was determined using Fellegi's (2003) sampling technique with a 95% confidence level. From a population of 3,738,430 farmers, 400 farmers were then selected as the core sample for this study. Baseline data collected from the Ministry of Agriculture helped in identifying 86 farmers who benefited in 2014 from a subsidy for

the adoption of ITTPF. This grant was awarded to them through PNIASAN and PASA implemented by the government in Togo (the Ministry of Agriculture) with help from FAO and financial support from the World Bank in which they voluntarily participated. The total sample of 400 respondents was broken down by region according to the weight of each region in the national agricultural population.

The 86 farmers exposed to ITTPF were distributed in the five regions of the country and by district. They were therefore considered as the beneficiaries and were part of the overall sample. Three hundred and fourteen (314) non-beneficiary farmers, randomly selected from the population using a baseline dataset, constituted the rest of the sample and were also stratified according to the weight and distribution of farmers subsidized by the district. Key socioeconomic variables, institutional characteristics, livestock ownership, production costs, income and expenditure were all collected.

On September 20, 2017, this study received approval and financial support from the German Academic Exchange Service (DAAD) for its implementation. The DAAD is a joint organization of the universities and other institutions of higher education in the Federal Republic of Germany. Supported from public funds, the DAAD promotes international academic cooperation, especially through the exchange of students and academics. This research project has been funded by the DAAD under the reference numbers 57377171, 57423580 and 57520399. At the beginning of the study, the research proposal was submitted to the DAAD selection committee in Germany comprising a panel of independent academics for consideration and approval. The committee was transparent in its functioning and was independent of the researchers, the sponsors and any other stakeholders. Before fieldwork and data collection from respondents in Togo, authorization was obtained from the Ministry of Agriculture, Livestock and Rural Development (MAEDR) through its Advisory and Technical Support Institute (ICAT), under reference number 0325/ICAT/DRH/DCIFS. The article does not include any animal studies conducted by any of the authors. We did not collect any confidential or private information about the farmers. All individual participants in the survey provided verbal consent to be interviewed after being informed about the purpose of the study. Upon the study's completion, the researchers submitted a final report to the DAAD, encapsulating a summary of the study's findings, conclusion and recommendations.

After performing the statistical and econometric analyses, the *t*-test results are presented in Table 2, the average impact results are shown in Table 3, and Tables 4, 5, 6 and 7 contain the heterogeneous impact results.

4. Results and discussions

4.1. Descriptive statistics

Table 1 compares the different technology components adopted by treated and untreated farmers in

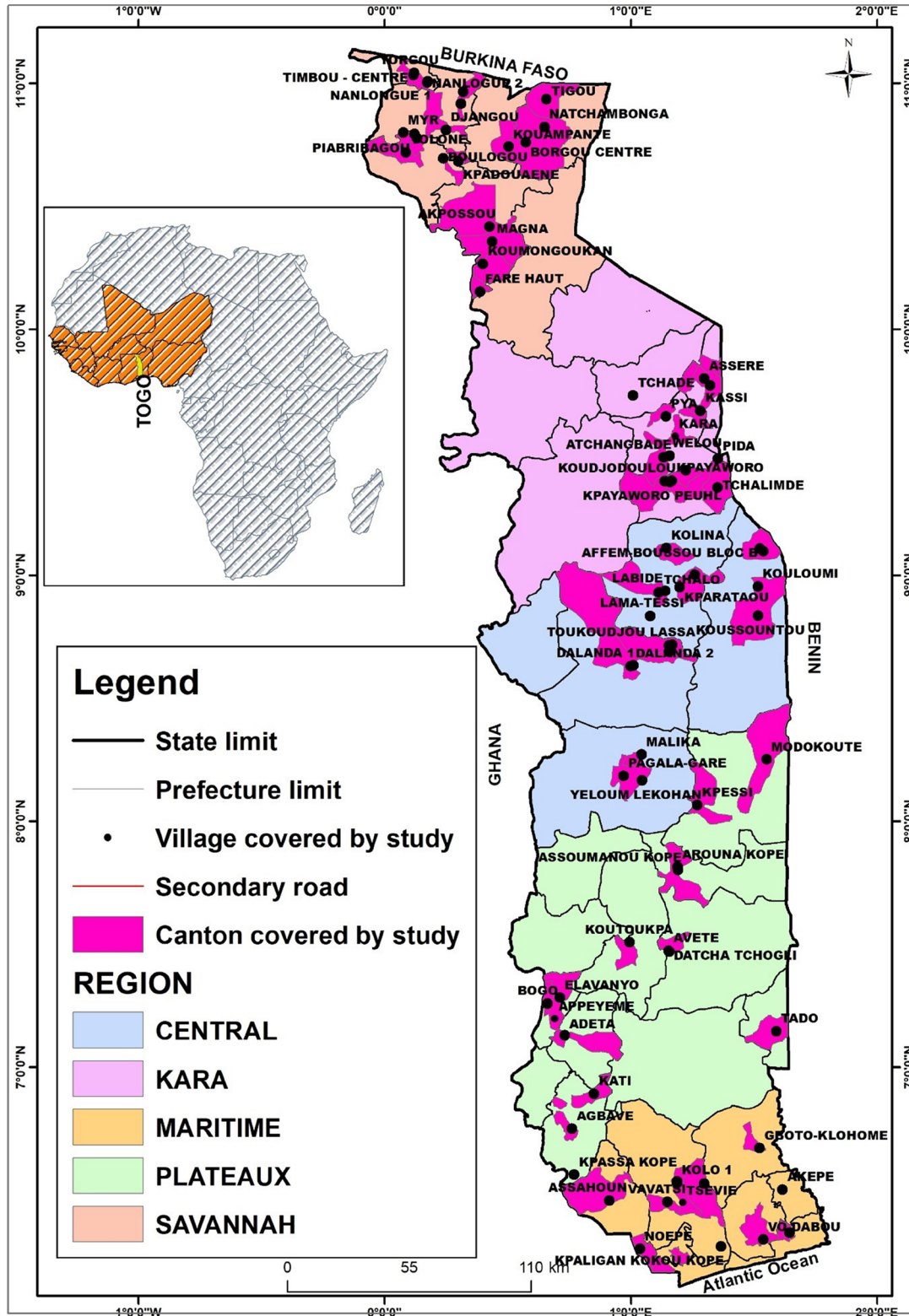


Figure 1. Map of the study area (Togo)
Source: Author's own design

Table 1. Comparison of different technology components among the treated and untreated farmers

Program poultry categories	Technology components	Untreated farmers	Treated farmers
		Traditional poultry farming Smallholder and backyard systems	Improved traditional poultry farming Semi-intensive systems
Chickens Guinea fowl Ducks Turkeys	Poultry farm	Free-range rearing with or without traditional poultry dormitories	Semi-modern poultry housing featuring five compartments equipped for both indoor and outdoor management practices
	Poultry breeds Breeding protocol	Local or indigenous poultry breeds Traditional breeding methods based on local knowledge and cultural practices	Local and improved local poultry breeds Semi-modern breeding methods, integrating modern, commercially oriented approaches with traditional knowledge
	Poultry feed ration Breeding equipment	locally available feed resources Traditional poultry farming equipment	Balanced poultry feed ration available at lower cost Semi-modern equipment such as feeders, waterers, nesting boxes, incubators, hatcheries, brooders, scales, etc.
	Health management and disease control Incubation	Traditional health management Natural incubation	Modern health management: hygiene practices, prophylaxes and vaccination protocols Natural and artificial incubation using incubators, hatcheries, and brooders
	Advisory and technical support services	No or infrequent advisory and technical support services	Comprehensive advisory and technical support services, including training, capacity building and expert monitoring and evaluation
	Financial resources	Very low equity	Limited working capital

Source: Authors' conceptualization based on field data.

Table 2. Student test (*t*-test) on potential outcomes of both the treated and untreated groups of farmers before and five years after the implementation of the program

Potential outcomes	Before the program	After the program
	Student test (<i>t</i> -test)	Student test (<i>t</i> -test)
Loss rate of poultry	0.55	56.38***
Hatching rate of eggs	3.30***	-22.93***
Farm size	-12.57***	-12.12***
Annual sale of poultry	-12.33***	-14.47***
Turnover	-11.23***	-8.54***
Profit	-11.24***	-8.37***

Source: Authors' computation based on field data.

***Statistical significance at the 1% level.

Table 3. Estimates of the average impact of the program

Potential outcomes	Difference-in-differences (ATET)
Loss rate of poultry	-0.62*** (0.0156)
Hatching rate of eggs	0.28*** (0.0144)
Annual sale of poultry	0.0228*** (0.0017)
Turnover	0.2241*** (0.0277)
Profit	0.1294*** (0.0166)

Notes: Standard errors are in parentheses. ATET: average treatment effect on the treated. Annual sale of poultry, turnover and profit are estimated at the 10,000th scale.

Source: Authors' computation based on field data.

***Statistical significance at the 1% level.

their respective poultry farming systems after program implementation. Table 2 shows the *p*-values of Student's *t*-tests on the potential outcome variables before and five years after the implementation of the program. Except for the *p*-value of poultry loss rate before program implementation, all the remaining are less than 1%. These findings suggest that farmers were not assigned to the program randomly. Results

Table 4. Estimates of heterogeneous impact controlling for the amount of subsidy received by program beneficiaries

Potential outcomes	Heterogeneous impact evaluation	
	Difference-in-differences	
	Standard grant	Sub-standard grant
Loss rate of poultry	-0.61*** (0.0192)	-0.63*** (0.0234)
Hatching rate of eggs	0.30*** (0.0182)	0.26*** (0.0221)
Annual sale of poultry	0.0192*** (0.0012)	0.0282*** (0.0023)
Turnover	0.1610*** (0.0102)	0.3206*** (0.0416)
Profit	0.0922*** (0.0062)	0.1862*** (0.0250)

Note: Standard errors are in parentheses. Annual sale of poultry, turnover and profit are estimated at the 10,000th scale.

Source: Authors' computation based on field data.

***Statistical significance at the 1% level.

also indicate that after five years of the implementation of the program, there is a significant difference between the means of potential outcomes variables such as poultry loss rate, hatching rate of eggs, farm size, annual sale of poultry, turnover and profit for both the treated and untreated groups of farmers. The impact evaluation of the adoption of ITTPF on

Table 5. Estimates of heterogeneous impact controlling for the functional status of improved traditional poultry farms five years after program implementation

Potential outcomes	Heterogeneous impact evaluation	
	Difference-in-differences	
	Improved farm in good condition	Improved farm not in good condition
Loss rate of poultry	-0.61*** (0.0190)	-0.63*** (0.0238)
Hatching rate of eggs	0.30*** (0.0182)	0.26*** (0.0221)
Annual sale of poultry	0.0305*** (0.0017)	0.0110*** (0.0016)
Turnover	0.3077*** (0.0336)	0.0963*** (0.0111)
Profit	0.1790*** (0.0202)	0.0535*** (0.0068)

Note: Standard errors are in parentheses. Annual sale of poultry, turnover and profit are estimated at the 10,000th scale.

Source: Authors' computation based on field data.

***Statistical significance at the 1% level.

Table 6. Estimates of heterogeneous impact controlling for standard amount of subsidy received by the beneficiaries and the functional status of improved traditional poultry farms five years after program implementation

Potential outcomes	Heterogeneous impact evaluation	
	Difference-in-differences	
	Standard grant and improved farm in good condition	Standard grant and improved farm in poor condition
Loss rate of poultry	-0.60*** (0.0253)	-0.61*** (0.0278)
Hatching rate of eggs	0.33*** (0.0246)	0.26*** (0.0262)
Annual sale of poultry	0.0287*** (0.0012)	0.0082*** (0.0010)
Turnover	0.2248*** (0.0103)	0.0867*** (0.0087)
Profit	0.1302*** (0.0064)	0.0477*** (0.0055)

Note: Standard errors are in parentheses. Annual sale of poultry, turnover and profit are estimated at the 10,000th scale.

Source: Authors' computation based on field data.

***Statistical significance at the 1% level.

the potential outcomes of program beneficiaries is thus justified and is essential to quantify the added value created by this emerging agricultural practice among farmers in rural areas.

Since the assignment of farmers to the program was not random, to have a better control for selection bias, the use of an appropriate econometric impact evaluation method is crucial. To have better control of unobservable socioeconomic characteristics of farmers and because the treated group in this study is not large enough to satisfy the assumption of common support, furthermore, because the baseline and follow-up program data are available for both the treated and untreated groups, the DD impact evaluation model under the parallel-trend assumption is used to evaluate the average and

Table 7. Estimates of heterogeneous impact controlling for sub-standard amount of subsidy received by the beneficiaries and the functional status of improved traditional poultry farms five years after program implementation.

Potential outcomes	Heterogeneous impact evaluation	
	Difference-in-differences	
	Sub-standard grant and improved farm in good condition	Sub-standard grant and improved farm not in good condition
Loss rate of poultry	-0.62*** (0.0275)	-0.66*** (0.0421)
Hatching rate of eggs	0.26*** (0.0262)	0.24*** (0.0403)
Annual sale of poultry	0.0326*** (0.0022)	0.0178*** (0.0026)
Turnover	0.4045*** (0.0477)	0.1193*** (0.0160)
Profit	0.2357*** (0.0286)	0.0673*** (0.0099)

Note: Standard errors are in parentheses. Annual sale of poultry, turnover and profit are estimated at the 10,000th scale.

Source: Authors' computation based on field data.

***Statistical significance at the 1% level.

heterogeneous impacts of ITTPF adoption on poultry loss rate, hatching rate of eggs, poultry sales, turnover and profit of farmers in Togo. Note that the heterogeneous impacts are estimated based on the amount of subsidy received by the beneficiaries and the functional status of their improved poultry farms five years after program implementation. The amount of subsidy is defined as a standard or sub-standard grant. The standard grant is equal to US\$ 6364 while the sub-standard grant is equal to any amount less than US\$ 6364. Functional status indicates whether or not the improved poultry farm of a given treated farmer is still operational five years after program implementation.

4.2. Econometrics results

Five years after the implementation of the program, the average impact estimates (Table 3) show that the loss rate of poultry has been reduced on average by 62% and the hatchability percentage or the hatching rate of eggs has been increased on average by 28% for each farmer in the treated group. These results are explained by the fact that the semi-intensive system of improved traditional poultry production has reduced poultry losses and raised hatchability percentages associated with traditional free-range poultry rearing.

In addition, the observance of technical itineraries of production such as the improvement of the poultry dormitories as well as the regular supply of quality and balanced feeds to poultry, and the observance of hygiene and health care rules have enabled

farmers to considerably increase the hatching rate of eggs and to reduce the mortality rate and thus the losses due to diseases, especially viral diseases, which are the main bottlenecks in traditional poultry farming. According to Magothe et al. (2012), the use of feeding and watering equipment by farmers on their improved traditional poultry farms is very important for a healthy and, balanced diet and enables those farmers to practice the sanitary measures indispensable for the reduction of mortality. According to Kumaresan et al. (2008), a poultry project directorate established by the Indian Council of Agricultural Research in Mizoram enabled smallholders in rural areas to improve traditional free-range poultry production.

The annual sale of poultry increased on average by 228 birds for each beneficiary. This advancement in poultry sales resulted in an average increase in annual turnover by US\$ 2241 and a subsequent increase in average annual profit by US\$ 1294 per farmer, after deduction of production costs. This average annual profit of US\$ 1294 recorded per farmer in the treated group constitutes the added value resulting from the adoption of ITTPF. This added value considerably improves the income level of program beneficiaries and enables them to meet their livelihood needs between agricultural production seasons. It also contributes to strengthening their resilience to the continuous decline in productivity and income from crop production due to the adverse effects of climate change, declining fertility of arable land, and land-use constraints.

The average impact assessment of the program confirms that the adoption of ITTPF provides farmers with additional economic activity enabling them to improve their livelihoods, diversify their sources of income, create wealth and significantly reduce poverty in rural areas. These findings are in line with those of Asfaw et al. (2012), Awotide et al. (2015), Belay and Mengiste (2021), Bhattacharyya et al. (2023), and Mendola (2007) who also found that the adoption of agricultural technologies has a positive and significant impact on farmers' livelihoods, income levels and well-being.

While the average impact helps in assessing the treatment effect on the entire treated group, the heterogeneous impacts allow to conduct a more in-depth evaluation study by categorizing the treated group based on the amount of subsidy received and the functional status of the improved traditional poultry farms five years after the implementation of the program.

Controlling for the amount of subsidy received by the beneficiaries of the program (Table 4), the annual profit has increased on average by US\$ 922 for each beneficiary of the standard grant. While for each beneficiary of the sub-standard grant, the annual profit has increased on average by US\$ 1862. These results can be explained by the fact that the beneficiaries of the sub-standard subsidies comply much more with the technical itineraries of production and they are also specialized in improved traditional rearing of the most profitable poultry such as turkeys and guinea fowl. These findings mean that the subsidy is a necessary condition for ITTPF adoption, but not sufficient for the optimization of profitability.

Controlling for the functional status of the improved traditional poultry farms (Table 5), the annual profit has increased on average by US\$ 1790 for each beneficiary whose improved poultry farm is functional and in good condition. While the annual profit has increased on average by US\$ 535 for each beneficiary whose improved poultry farm is in poor condition. These results confirm that poor condition, unstable functioning or total non-functioning of some improved poultry farms five years after the implementation of the program are among the main factors that do not contribute to the effective, efficient and optimal achievement of the program's expected results.

The combination of the above two eventualities in the treated subpopulation, that is, the amount of subsidy received as well as the functional status of the improved poultry farms five years after program implementation yields the following results (Tables 6 and 7). While the annual profit has increased on average by US\$ 2357 for each beneficiary who received the sub-standard grant and whose improved poultry farm is functional and in good condition, it has increased on average by US\$ 1302 for each beneficiary who received the standard grant instead and whose improved poultry farm is in the same condition. Furthermore, the annual profit has increased on average by US\$ 673 for each beneficiary who received the sub-standard grant and whose improved poultry farm is in poor condition, while it has increased on average by US\$ 477 for each beneficiary who received the standard grant instead and whose improved poultry farm is also in poor condition (Appendix).

Despite the difference in the subsidies provided to farmers, the heterogeneous impact evaluation results reveal that the best program impact is achieved by the sub-population of beneficiaries who received the

sub-standard grants and whose improved poultry farms are still functional and in good condition five years after the implementation of the program. Specifically, in this sub-population of beneficiaries, the annual profit has increased on average by US\$ 2357 for each farmer.

These results indicate that not only did this sub-group of beneficiary farmers choose to raise local poultry species with high wealth-creation potential, such as turkeys and guinea fowl, but also to implement the itineraries and technical packages indispensable for successful ITTPF adoption. Beneficiary farmers in this sub-group demonstrated exceptional motivation and unwavering commitment to embracing the ITTPF adoption program. They viewed it as a transformative opportunity to bolster their resilience, enhance their livelihoods and create a sustainable source of income for poverty alleviation and development in rural areas.

Although the added value from adopting ITTPF is considerable, it could have been much greater if the adoption rate had been close to 100% among the beneficiaries and if, five years after the implementation of the program, all the improved poultry farms were highly functional and in good condition. After receiving their subsidies, the motivation of certain beneficiaries to give the best of themselves by scrupulously respecting the itineraries and technical packages of ITTPF adoption for optimal results achievement has not been consistent and permanent. These findings are similar to those of Issahaku and Abdulai (2020), Khonje et al. (2015), Schulz and Börner (2023), Tambo and Mockshell (2018) who also found, after impact assessment analyses, very significant differences between the average and heterogeneous impact estimates of agricultural technologies adoption.

During the fieldwork, it was observed that there are abandoned and non-functioning poultry farms in the program for the simple reason that some beneficiaries, after having obtained funding for the adoption of ITTPF, had abandoned the program to invest in other economic activities. Another reason why the added value of this program is not optimal is the lack of incubators, hatcheries, and brooders, their poor quality or their difficulties in functioning well in rural areas and especially the lack of training of program beneficiaries on how to use and optimize the performance of these breeding equipment knowing that their manipulations require more professionalism and technical skills. We found in the field that the majority of incubators, hatcheries, and brooders made available to farmers who received grants from

the program are electric, while in most of the poultry farms created under the program, there is no electricity. Concerning the acquisition of vaccines and other prophylaxis products available in the approved units installed for the most part in the city centers, the isolation of the program's improved poultry farms has not at all made it easier for the beneficiaries to rigorously respect the hygiene and health care of poultry. Furthermore, the lack of continuous training, technical, organizational, and managerial capacity building, and the lack of periodic monitoring-evaluation of all program beneficiaries by the experts, public, and private structures involved in the program do not promote the full adoption of ITTPF.

According to the farmers surveyed during the fieldwork, the non-achievement of the program's optimal results is also due to some social facts. The majority of female beneficiaries of the program find it difficult to engage fully in the adoption of ITTPF. These female beneficiaries are often forced by their husbands to abandon this activity which occupies them and prevents them from fulfilling their duties as housewives. Men are also concerned about the fact that through this program, their wives will take financial control of the households, and this will lower their decision-making power as male household heads. According to the respondents, some beneficiaries of this program saw their families threatened. It should be noted that at the end of the fieldwork, among the beneficiaries, two cases of death were recorded.

5. Conclusion and policy recommendations

The objective of this research is to evaluate the impact of Improved Technology adoption in Traditional Poultry Farming (ITTPF) on farmers' potential outcomes in Togo. Our empirical findings substantiate that the program aimed at fostering the adoption of ITTPF has resulted in significant economic impacts on the potential outcomes of beneficiaries. Specifically, the program has endowed farmers with a supplementary economic activity, for additional income generation, wealth accumulation and poverty alleviation. The added value from the program considerably improves the income levels of beneficiaries and enables them to meet their livelihood needs between agricultural production seasons. It also contributes to strengthening their resilience in the face of the continuous decline in productivity and income from crop production due to adverse weather conditions, decrease in soil

fertility and land-use constraints. Although the added value from the adoption of ITTPF is considerable, it could have been better if the adoption was complete among program beneficiaries.

In terms of policy recommendations for sustainable agricultural development, we encourage farmers to join agricultural cooperative societies to benefit from the services these cooperatives provide to their members such as information, awareness, literacy, training, creation of value chains through agricultural cooperatives networking, access to input and financial credits, access to national and international markets for the valorization of agricultural commodities. Farmers should develop a sincere collaboration with extension and technical supervision services to benefit from the exogenous knowledge promoted by these structures, maintaining a brotherhood spirit and sharing technical skills and experiences among themselves. To enhance the profitability of ITTPF adoption, farmers should benefit from periodic programs of training, technical and organizational capacity building, monitoring, evaluation, and advisory support. It is essential to provide beneficiaries with quality breeding equipment, in sufficient quantity and adapted to energy systems appropriate for rural areas. Program participants should receive continuous technical training on the optimal use of breeding equipment. Hygiene and health care products should be available and close to the improved poultry farms. It would be necessary to install a source of potable water supply to be given to poultry near the improved poultry farms. It is essential to build a cold room in each improved poultry farm with a renewable energy system for the conservation of hatching eggs as well as for the conservation of hygiene and vaccination products. It is vital to assist program beneficiaries in their search for national and international outlets for the valorization of their poultry products and by-products. For agricultural transformation and sustainable development, the government's agricultural policy should mobilize more resources and invest in large-scale technological innovation, with an incentive policy to promote the adoption of agricultural technologies by the majority of farmers. Agricultural policy should encourage farmer organizations such as agricultural cooperatives, as well as effective extension services, to ensure the widespread adoption of improved agricultural technologies. The government should implement the instruments of the chain planning, programming, budgeting, execution, monitoring and evaluation of all agricultural development programs and projects to allow progressive

adjustments for effective, efficient and optimal results achievement.

We conclude this article by acknowledging a limitation of our study. While our investigation focused mainly on quantitative and economic aspects of traditional poultry farming, we did not collect data regarding the quality of poultry meat after implementation and adoption of improved technology by farmers. Future research endeavors may aim to comprehensively explore this aspect, thereby contributing further to knowledge in the field of food and nutrition.

Notes

1. In 2003, the Assembly of the AU that was held in Maputo committed to the allocation of at least 10% of national budgetary resources to develop the rural regions and agricultural sector in Africa, which is also part of the AU's agenda 2063.
2. Turnover and Profit are estimated in USD (US\$ 1 = XOF 550 at the time of the study).

Authors' contributions

M. K. Soviadan: Conceptualization, design, methodology, sampling design, data collection, data analysis and interpretation, original draft preparation, writing and editing. O. Ahmed, Z. Kubik, and A. A. Enete: Methodology, data visualization, editing, critical revision for improving intellectual content. C. U. Okoye, and T. Glauben: Editing, critical revision for improving intellectual content. All authors have given their consent for the publication of the manuscript and have agreed to be accountable for all aspects of the work.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The datasets generated and analyzed for this article are available from the corresponding author upon reasonable request.

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Appendix: Graphical results of parallel trends assumptions tests on potential outcomes of treated and untreated groups of farmers before and after treatment

