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Returns to livestock disease control – A panel data analysis from Togo

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Abstract

This paper investigates whether – and to what extent – a veterinary intervention program lead to improvements in small-scale cattle farmers' welfare using a unique panel data set of 443 households from northern Togo. Our results show a positive impact of the interventions on improving farmers' knowledge and husbandry practices which translates into improved livestock health and productivity. In addition, these positive effects trigger improvements in terms of poverty and vulnerability. The results highlight the important role of targeted interventions that aim to improve livestock health – a key asset among rural households in sub-Saharan Africa.

Keywords: livestock, poverty, vulnerability, interventions, fixed-effects, sub-Saharan Africa

JEL Classification: C36, I30, Q10, Q16

1. Introduction

Agricultural production is a major source of household livelihood in sub-Saharan Africa (SSA), offering employment to approximately 60% of the population (IMF, 2014; World Bank, 2014). To sustain their livelihoods, the rural poor must diversify their income sources and strengthen their productive assets to prevent their income from falling below a critical level. Growth in the agricultural sector must continue if poverty in SSA is to decline, mainly because agriculture is more inclusive than formal employment (Taffesse & Tadesse, 2017; Ravallion *et al.*, 2007). Livestock, especially cattle, are an important component of household agriculture in the northern regions of Togo. Cattle serve a multitude of purposes, including draft power for farm cultivation, manure, store of value (insurance), and emergency income, and they supplement the nutritional needs of households (Pica-Ciamarra, 2015; Kazianga & Udry, 2006).

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Furthermore, in the context of nonexistent off-farm employment opportunities and imperfect credit and insurance markets, cattle remain the only channel into the liquid economy.

However, cattle production is constrained by African animal trypanosomosis (AAT), a livestock disease that has a considerable negative economic effect on household livelihoods. It is estimated that in the SSA region, the disease causes losses of approximately US\$ 4.5 billion dollars, including trade losses, cattle mortality, disease control costs and a loss of productive farm working hours (Cecchi & Mattioli, 2009; FAO, 2011; Bud, 1999). At the household level, AAT has direct negative implications for household well-being, such as increased vulnerability to food insecurity and a reduced ability to mitigate idiosyncratic and systemic shocks that could lead to income loss (Liebenehm *et al.*, 2011a). For example, Affognon (2007) found that cattle farmers in Mali and Burkina Faso lose approximately €9.50 to €22.00 per tropical livestock unit (TLU) p.a. as a result of AAT.

Current control and prophylactic measures remain ineffective or unsustainable and often result in drug resistance (see Clausen *et al.*, 2011; Grace *et al.*, 2009). Thus, an international multidisciplinary team of scientists, acting in cooperation with governmental and nongovernmental stakeholders with funding from the European Commission, launched the so-called trypanosomosis rational chemotherapy (TRYRAC) program in 2012 (www.trypanocide.eu) to improve small-scale farmers' AAT management practices. TRYRAC is an integrated approach that involves a combination of preventive and curative measures with the goal of reducing overall disease prevalence, encouraging the responsible use of trypanocides to reduce drug resistance and improving the general health condition of animals (WHO, 1987). TRYRAC interventions have promoted an integrated approach to disease control, including participatory extension methods, such as mass media, and trainings for selected farmers on good husbandry, tsetse control, and worm and tick control strategies.

In this paper, we investigate whether and to what extent livestock disease control interventions improve the welfare of small-scale cattle farmers. We collected household panel data on farmers who participated in the TRYRAC program and those who did not, both before and after the TRYRAC intervention took place. This dataset enables us to estimate the impact of AAT control on household welfare. More specifically, we proceed as follows. First, we analyze whether disease control interventions improved cattle farmers' knowledge and disease control practices which, in turn, may lead to improvements in animal health. We assume that increased knowledge could be different from the actual adoption of practices because the adoption

decision may be driven by other confounding factors. Second, we investigate the impact of disease control interventions on farm households' welfare, measured as per capita consumption, poverty headcount and vulnerability to poverty.

The paper is among the first to conduct a rigorous impact assessment of livestock disease control in SSA. While the literature on the impacts of technology targeted to livestock is scant, our study complements recent empirical literature on the impact of crop technologies on household well-being in SSA (see Amare *et al.*, 2012; Shiferaw *et al.*, 2008; Asfaw *et al.*, 2012; Kassie *et al.*, 2011). Our study is unique in several ways. First, this study focuses on a region characterized by high poverty, a lack of formal employment opportunities and a lack of credit and input markets. Thus, the study provides new insights for policy recommendations that would improve the livelihoods of vulnerable households in SSA. Second, to the best of our knowledge, this study is the first to evaluate the impact of interventions in the livestock sector at the household level using panel data. Third, the study examines broader welfare outcomes, going beyond stochastic household poverty, to investigate vulnerability to poverty as a determinant of future welfare.

Our estimation procedure uses different methodological approaches to deal with program endogeneity and self-selection bias issues with impact estimation. Overall, the results suggest that the TRYRAC intervention has a positive impact on rural household welfare outcomes. In particular, the empirical results show that by participating in the interventions, households can increase their livestock productivity and reduce the prevalence of AAT and other disease infections in 2016. We show that an increase in productivity has contributed to an increase in household consumption per capita while reducing the probability of falling into stochastic poverty and vulnerability.

The rest of the paper is structured as follows. In section 2, we describe the intervention. The empirical and theoretical methods are presented in section 3. The study area, data setting and collection methods are described in section 4. Section 5 presents the results and discussion, and section 6 summarizes the paper and presents the study's conclusions.

2. Background of the TRYRAC intervention program

2.1.1. Background information

AAT is caused by *Trypanosoma spp.*, a pathogen transmitted by the tsetse fly (*Glossina spp.*). [Alsan \(2015\)](#) recently identified the tsetse fly as a historical constraint to economic development in SSA. While acute cases of the disease are fatal, most cases of AAT are chronic, affecting animals over a longer time period with a loss of appetite, prolonged diarrhea and reduced productivity ([Simarro et al., 2011](#)). Estimates put the cost of AAT in SSA at approximately US\$4.5 billion through animal mortality, lost productivity and treatment cost ([Swallow, 2000](#); [FAO, 2011](#)). At the household level, AAT leads to production, consumption and income losses, which perpetuate poverty and food insecurity among the rural poor ([Fafchamps et al., 1998](#); [Perry et al., 2002](#); [FAO, 2011](#)). The effect of AAT is high in northern Togo, which is regarded an important cattle production zone. For this reason, the European Union, through its Global Program for Agriculture Research for Development, funded the trypanosomosis rational chemotherapy (TRYRAC) intervention, targeting small-scale cattle producers in the Kara and Savana regions of Togo.

The TRYRAC project represents international cooperation by academic, governmental and nongovernmental organizations aimed at optimizing AAT management in SSA-Togo, Mozambique and Ethiopia. The overall objective is to improve the livelihoods of resource-poor small-scale livestock (cattle) keepers in the selected countries. The project has been implemented in three phases, i.e., (i) baseline, (ii) implementation and (iii) endline. In the first phase, a baseline survey was conducted to identify AAT prevalence rates in each of the project countries. For Togo, this rate was identified in the Kara and Savana regions, in which AAT prevalence rates range between 24% and 28% ([Tchamdja et al., 2016](#)). Socioeconomic data at the household level, village information and epidemiological data were then collected in 2013. The second phase involved the rollout of the interventions simultaneously across randomly selected treatment villages in the Kara and Savana regions starting in 2014. For the purposes of project implementation, the selection of sample villages followed a two-step random sampling approach. At the first stage, 20 villages were randomly selected from 72 villages in Kara and Savanes regions with recorded AAT prevalence and livelihoods depending on cattle keeping. At the second stage, the 20 selected villages were randomly assigned to treatment (7 villages) and control (13 villages) groups. All of the cattle keepers in the treatment villages were eligible to participate in the program interventions. Thus, the problem of self-selection needs to be addressed in the estimation approach that we describe in our identification procedure in the next section. To reduce cross-contamination of the controls to the lowest minimum possible, the control and the treated villages were at least 65 km apart.

The TRYRAC intervention was composed of two components and implemented by local experts from Institut de Conseil *et* D'appui Technique (ICAT) and Veterinaires Sans Frontiers (VSF), together with support from local veterinary and village cattle herder associations in the treatment villages. First, participatory extension methods (e.g., mass media and posters) were used to educate cattle farmers on improved production practices, specifically AAT management. Second, training sessions were organized for cattle farmers on good husbandry and tick and worm control. During the implementation period, farmers in treated villages continually received education, training and other information relative to AAT management. However, the project did not provide direct subventions, such as subsidies or inputs.

Finally, in 2016, an endline survey was conducted with the same households that participated in the baseline survey in 2013. Repeated observations of identical households before and after the intervention facilitates a rigorous assessment of economic impacts. However, as farmers in treatment villages self-select into the intervention, we must account for potential biases arising from self-selection. Before describing our methodological approach, we briefly introduce the data collection processes during the baseline and endline surveys in the following section.

2.1.2. Data

To determine the impact of the TRYRAC program, we use two rounds (2013/2016) of household-level survey data from 500 randomly selected households (25 per village) in the Kara and Savanes regions of Togo. The sampling frame was a list of all cattle-keeping households each village prepared in consultation with the village head and local veterinary office. Formal household interviews were implemented using a structured pretested questionnaire and were administered by experienced and trained local enumerators. The household head or person responsible for making major cattle production decisions was interviewed. To reduce enumerator bias, we ensured that none of the stakeholders, such as veterinary personnel, were used or involved in the questionnaire administration. Enumerators were mainly selected from Kara University and were required to speak at least one of the local dialects and to understand the farming system in the study area. This step was taken to reduce noise in the data, given that most cattle farmers have little or no formal education (2 years on average) and depend on recall data.

During the baseline survey in 2013, demographic, consumption and income data were collected at the household level. Additionally, each household's knowledge, attitudes and practices related to AAT were also collected. Furthermore, general cattle management practices in terms

of worms, ticks, and feeding have been collected. These questions were in line with the knowledge, attitudes, and practices (KAP) questionnaire guidelines used in similar studies for livestock disease control ([Tornimbene et al., 2014](#); [Grace et al., 2009](#); [Liebenehm et al., 2011b](#)). For a detailed description of the questionnaire, refer to [Weyori et al. \(2018\)](#). The follow-up survey was conducted in May 2016, two years after the interventions were rolled out, using the baseline questionnaire with an additional section to identify the treated households. More than 93% of the baseline households (476) were interviewed during the impact survey with an attrition² rate of 6.8%, or 33 households. We restricted our study to households for which sufficient information was available in both survey waves to form a balanced panel of 443 unique households. For purposes of the impact estimation we define treated households as the ones that participated in the TRYRAC program activities, while those households that did not participate in the interventions are considered as controls.

² There were three main reasons for attrition. First, some of the households moved out of their original villages and hence could not be traced during the impact survey. Second, other households (18 households) refused outright to participate in the impact survey because they had expected to be remunerated during the baseline survey, which was not the case. Third, the final group of households was left out on purpose because their baseline data were insufficient, missing or incomplete, thus restricting any useful impact analysis.

3. Methodology

3.1. Identification and empirical estimation strategies

The estimation of TRYRAC's impacts at the household level is not a trivial exercise because of the potential selection bias and endogeneity associated with the program's setup. However, the availability of panel data allows us to follow numerous quasi-experimental identification strategies to estimate the impact. Specifically, we exploit the fact that project villages were randomly selected for treatment and control to implement the difference-in-difference fixed-effects estimator and the two-stage least squares (2SLS) fixed-effects instrumental variable (FE-IV) approaches. We also implement a propensity score matching approach based on baseline covariates to assess the robustness of the fixed effects and 2SLS results.

3.1.1. Difference-in-difference fixed effects

We specify the impact of the TRYRAC intervention as follows:

$$Y_{it} = \delta_t + \tau_i + \alpha(\dot{D}_i * T_{post}) + \beta_1 X_{it} + \beta_2 V_{jt} + \varepsilon_{it} \quad (1)$$

where Y_{it} is the outcome variable (Y = knowledge score, practices, AAT prevalence, veterinary expenditures, productivity (livestock net income), household income per capita, and consumption per capita) of the i^{th} household in period t ($t=2013, 2016$) and T_{post} is a binary indicator for the post-intervention period (2016). $\dot{D}_i$ is the treatment status of the i^{th} household. The interaction term $\dot{D}_i \times T_t$ captures the treatment effect of TRYRAC. We also include X_{it} and V_{jt} , a rich set of exogenous time-varying household- and village-level characteristics, respectively. δ_t and τ_i are time and household fixed effects. ε_{it} is the idiosyncratic additive error term with a zero-mean. The standard errors are clustered at the village level to account for serial correlation. The DD-fixed effects estimation eliminates the double jeopardy of selection bias arising from households' unobserved confounders and time trends in outcome of variable through the common trends assumption, which implicitly assumes that (i) unobserved heterogeneity causing self-selection are time-invariant and additive, and (ii) the outcomes of treated and control households would follow a similar trend over time in the absence of the treatment³. Although we are not able to perform an empirical falsification test of the second

³ Intervention villages were randomly selected from a pool constructed based on their similarities and to the best of our knowledge, there were no parallel or similar ongoing interventions that differently affected participants and non-participants in the study villages to violate our parallel trends assumption.

assumption of the common trends assumption because of the absence of long pre-intervention data, the systematic similarities between treatment and control villages at the baseline presents a strong basis to assume this assumption holds true. Furthermore, a pre-intervention comparison of treated and control households does not show any significant differences on key characteristics and the outcome variables (see Tables 5 and 4).

The issue of self-selection bias from unobserved household heterogeneity in eqn. 1 is eliminated through the fixed effects assumption⁴ as long unobservable confounders are time-invariant.

In our estimation we further control for any observable pre-intervention conditions by implicitly controlling for pre-treatment observed time-varying covariates that are correlated with the treatment decision of households but remain exogenous to the treatment itself.

Finally, we estimated the DD-fixed effects of the form

$$Y_{it} = \alpha(\hat{D}_i * T_{post}) + \beta_1 X_{it} + \beta_2 V_{jt} + \varepsilon_{it} \quad (2)$$

However, a violation of the unobserved time-invariant assumption where treatment decision is correlated with time-varying unobservable heterogeneity could affect the consistency of the DD estimator. To further test the consistency of our DD-fixed effects result, we also estimate a 2SLS FE-IV. We describe this approach in the next section.

3.1.2. *Fixed-effects instrumental variable approach*

The estimation of equation (2) could suffer bias if unobserved individual heterogeneity τ_i , is time-varying. This leads to omitted variable bias. The result is an error term that contains variables that are also correlated with the participation decision, i.e., $\text{cov}(\hat{D}_{it}, \varepsilon_i) \neq 0$, which violates the OLS assumption of independence between the covariates and the error term.

In the following, we relax the time invariant assumption of unobserved individual heterogeneity in eqn. 1 by instrumenting the treatment decision of the household to estimate the impact of TRYRAC by the fixed effects instrumental variable approach (FE-IV), in which the predicted values of decision to participate are fitted in the outcome equation. In this way we are able to

⁴ The unobserved fixed effects assumptions states that α is only unbiased and consistent for the i th household if τ_i is time-invariant, additive and $\text{cov}(\hat{D}_{it}, \tau_i) = 0$ (Angrist & Pischke, 2009; Wooldridge, 2010).

isolate the true impact of TRYRAC treatment decision from the effect contamination effect of the omitted unobserved individual heterogeneity.

In a two-stage process, we specify the two stage FE-IV estimation as follows.

In the first stage, we estimate the predicted propensity of the household to be treated through the instrumental variable Z .

$$\hat{D}_i = \beta_1 X_t + \gamma Z_{it} \quad (3)$$

In the second stage, the predicted probability of the i^{th} household to treat, $\hat{D}_i$, from eqn. 3 is plugged into the outcome equation (eqn. 4) as follows:

$$Y_{it} = \delta_t + \beta_2 X_t + \alpha(\hat{D}_i * T_{post}) + \varepsilon_{it} \quad (4)$$

Since treated villages have been randomly selected for the intervention, we instrument the household's decision to treat through a binary variable Z that equals 1 if a household is located in a treatment village and zero otherwise (Duflo *et al.*, 2008; Angrist & Pischke, 2009). We argue that households' decision to participate in the intervention may be highly correlated with the village treatment status. That is, residing in an intervention village increases the possibility that households access TRYRAC information, thereby participating in the intervention. This is expected to reduce the information asymmetry that would usually inhibit the adoption of new technologies among these households (Frölich & Lechner, 2010; McKenzie *et al.*, 2010; Makamu *et al.*, 2018).

The coefficient α in eqn. 4 gives the intention to treat effect (ITT) of TRYRAC, which is consistent under the assumption of exclusion restriction⁵. The estimated α under the assumption of independence and monotonicity is also interpreted as local average treatment effect (LATE) or impact of TRYRAC on the compliers, i.e., those who have been induced by the randomly assigned instrument to be treated (Imbens & Angrist, 1994). Given that our instrument meets these assumptions we interpret α as LATE of TRYRAC.

⁵ The exclusion restriction states that the instrument, Z , should be correlated with the decision to be treated and does not have a direct effect on the outcome variable, but only affects the outcome variable indirectly conditioned on treatment status. The first-stage regression results of our estimation show that our choice of instrument meets the exclusion restriction assumption (Appendix A. 1).

In addition to the above strategies, we estimate a parametric propensity score matching (PSM) approach for treatment and control households based on their baseline characteristics. We estimate the impact for treated households that are reasonably matched with control households within a common support. For brevity, the PSM results are reported in Appendix A4.

3.2. *Impact pathway and outcome variable definition*

Understanding the household-level impact pathways of any presumably welfare-enhancing interventions, such as the TRYRAC program, involves great complexities. We assume that the TRYRAC interventions first affect farmers' specific disease and disease management knowledge. The effect of improved knowledge may then lead to the adoption of improved practices. However, the adoption decision may depend not only on knowledge but also on access to and the availability of improved inputs. Third, once farmers' disease management knowledge and practices are improved, we may expect an improvement in animal health. Improved animal health could affect household welfare through at least four separate channels. First, as a source of protein through milk and meat, it can improve food security and nutrition. Second, draft power and manure are important inputs for crop production and improve household consumption. Third, additional income from the sale of livestock products and services and possibly crops, along with reduced production costs through improved animal health, can smooth household consumption and income shocks. Fourth, livestock sales can smooth consumption in cases of adverse events ([Rosenzweig & Wolpin 1993](#); [McPeak 2004](#); [Verpoorten 2009](#); [Islam & Maitra, 2012](#)).

Following the layout of these impact pathways, we first investigated the impact of TRYRAC interventions on farmer knowledge, which is measured based on aggregate scores on tests that ask questions about the causes and treatment of AAT⁶. Second, we investigate whether improved knowledge enhances the adoption of improved disease (AAT and worm) control practices rolled out through the TRYRAC program. Third, we examine whether improved

⁶The knowledge and practices scores were calculated by asking farmers questions and allocating scores according to three different knowledge categories:

- i. Disease-specific knowledge, e.g. symptoms, causes, mode of transmission, etc.
- ii. Curative and management knowledge of trypanosomiasis, including the quality and quantity of trypanocides usage, to administer medication;
- iii. Preventive and treatment knowledge based on as strategies adopted to manage AAT and other disease infections by the respondent.

Total accumulated points from (i) and (ii) gives the total knowledge score, while (iii) gives the practices score of the respondent. Following the integrated pest management approach for crops, categories are calculated as a percentage of the maximum possible score for each ([Tornimbene et al., 2014](#); [Liebenheim et al., 2011](#)).

knowledge and practices lead to improvements in animal health using the AAT prevalence rate in the herd, veterinary expenditures and animal productivity (given as total output values, i.e., the net income received by respondents from livestock output) as outcome indicators. Finally, we investigate the welfare impacts that are expected through improvements in animal health. To do so, we observe changes in consumption expenditures per capita and net benefits accrued to the household in per capita income as the result of reduced veterinary expenditures. To estimate the consumption expenditure per capita variable for the household, we include all household expenditure items in the last 12 months preceding the interview date for both periods (before and after). To calculate this, we pool the household total reported consumption expenditures at 2012 nominal prices adjusted by the adult equivalent scale. This includes all durable and nondurable goods and services consumed and used, respectively, by all household members. We define net livestock income as the total gross income from livestock products less input cost (veterinary service charge plus input costs), feed (if any), and hired labor (where applicable) per annum. We do not consider households' labor cost for herding animals because most households in this region depend on their own labor in cattle production; thus, the cost of a household's own labor resulted in negative income.

As a further welfare measure, we also estimate the impact of the interventions on stochastic poverty outcomes. Following [Foster *et al.* \(1984\)](#), we compute the Foster-Greer-Thorbecke (FGT) poverty measures (poverty incidence, poverty gap) comparing the per capita household income to the international US\$1.90 per day poverty line. Given the stochastic nature of household poverty, we therefore estimate the impact on future vulnerability to poverty. Households in SSA are often trapped in either transitory or structural poverty because of the absence of forward-looking interventions that consider their vulnerability to poverty.

Following the approach of [Chaudhuri \(2003\)](#) and [Hoddinott & Quisumbing \(2003\)](#), we estimate the impact of TRYRAC interventions on reducing vulnerability to poverty. We define household vulnerability to poverty, V_i , as the probability that the i^{th} household will record a consumption outcome that is below the poverty line defined as Z in $t+1$ period conditioned on households' socioeconomic characteristics (X_i), and other exogenous variables (β_n) at time t , i.e.,

$$V_{it} = \Pr(C_{it,t+1} \leq Z \mid X_i, \beta_n, \varepsilon_i) = \frac{Z - (\hat{C}_i - \hat{\sigma}_i)}{2\hat{\sigma}_i} \quad (5)$$

We classify households with a probability threshold above 0.5 as vulnerable to poverty and those below this threshold as not vulnerable. We estimate a reduced form of eqn. 5 in the form

$$V_{it} = \alpha T_t + \gamma X_{it} + \beta_1 S_{it} + \beta_2 \phi_t + \beta_3 \dot{D}_i + \mu_{it} \quad (6)$$

where T is a binary indicator for pre- and post-treatment periods and captures the time fixed effects, X_{it} refers to time-varying household characteristics, $\dot{D}_i$ is the program participation status of the i^{th} household, S_{it} and ϕ_t are reported idiosyncratic and covariate shocks. μ_{it} is the idiosyncratic additive error term with a zero mean. Eqn. 6 is estimated using a logit model.

4. Descriptive statistics

In this section, we present the descriptive statistics of the households. We look at their demographics, livestock holdings, knowledge and practices towards disease management, and income diversification strategies. These statistics provide an outlook of the sample and the quality of the counterfactual households used in the econometric estimations.

Table 1 shows the socioeconomic characteristics of the households by participation. Households do not differ significantly across categories. Household heads are, on average, 49 years old, married (polygamous), poorly educated (82% with no formal education) and less diversified in terms of income sources. The household size is generally large, ranging from 5 to 35, with a sample average of 10. The dependency ratio is 1.14. Crop production and livestock rearing constitute the main economic activities in the study area, contributing to more than 88% of total household income. The average farm size is 2.4 hectares, and crop production is 100% rainfed with no irrigation facilities.

Table 1: Descriptive statistics of households in treatment and control group at baseline (2013)

Variable	Pooled hh	Control hh	Treated hh	Diff.
HH age (years)	49	49.5	49	0.5
Household age grouping (%)				
18–24 years	2	2	2	0.0
25–34 years	15	14	15	1
35–44 years	25	25	25	0
45–54 years	25	23	27	4
55–65 years	20	20	19	1
> 65 years	14	16	13	1
HH gender (male=1)		0.96	0.99	
HH education category (%)				
No formal education	82	82	82	0
Primary education	10	12	9	3*
Secondary education	6	5	8	3*
Higher education	2	1	2	1
Household size	11	10	10	0
Farm size (hectares)	2.40	2.30	2.35	-0.05
More than 1 wife (1=yes)	0.89	0.87	0.90	0.03
Dependency ratio	1.14	1.13	1.15	-0.02
Social network (1=yes)	0.33	0.31	0.37	-0.06
Agriculture land owned (ha)	2.36	2.36	2.36	0
Income diversification (%)				
Agriculture (crop)	65	69	61	8
Agriculture (livestock)	23	20	30	-10
Off-farm	4	6	2	4
Self-employed	2	1	2	-1
Natural resources	2	2	2	0
Observations	443	229	214	

Note: HH denotes household head, *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' calculations

Livestock keeping is very prominent in the study area, as presented in Table 2. Respondents are typically small-holder livestock farmers with herd sizes ranging from 2 to 100 cattle and an average herd size of 9 cattle per household. Cows are kept mainly for reproductive purposes, while bulls are kept for traction and/or as a store of value. In addition to owning cattle, households kept other livestock, such as goats, sheep and chickens.

Table 2: Distribution of different livestock species kept by household

Livestock Type	2013		2016	
	Percent of households	mean herd size	Percent of households	mean herd size
Calves	21	7	21	6
Heifers	14	6	19	5
Cows	20	10	24	11
Bulls	25	5	24	3
Oxen	17	16	13	4
Sheep	28	10	28	15
Goats	28	8	29	9
Poultry	35	36	36	34
Pigs	7	6	6	9

Source: Authors' calculations

Table 3 presents the breakdown of the main livestock diseases that our sampled households reported. In particular, AAT remains a key constraint to cattle productivity in Togo. For example, more than 85% of the respondents in our sample reported the disease in their herd across the two survey waves. Although Table 3 shows a marginal drop in AAT incidences over time in the total sample, AAT still remains a major constraint for respondents. A disaggregation of AAT incidence by program participation status across the two waves shows a decline in AAT incidence (approximately 5%) in the intervention villages, while the control villages recorded a slight increase (2 percentage points) in AAT incidence.

Table 3: Top five diseases reported by respondents by treatment category

Disease incidence=yes	2013			2016		
	95%			87%		
Problem	Pooled (% hh)	Treated (% hh)	Control (% hh)	Pooled (% hh)	Treated (% hh)	Control (% hh)
Trypanosomosis	23	27	25	25	22	27
Tick and worm	12	11	18	15	13	13
Diarrhea	13	12	3	8	9	10
Skin abrasions	8	10	10	9	8	9
Injury	6	9	7	8	5	6
Observations	443	214	229	443	214	229

Source: Authors' calculations

In Table 4, we report the knowledge and practice scores of respondents as well as indicators of animal health. We found that participants' knowledge scores were significantly (28%) higher

than those of nonparticipants in 2016. The knowledge score indicates respondents' knowledge of ATT's causes, transmission, prevention and treatment. Similarly, participants' practice score, which is a total score measuring improved practices in managing AAT, ticks, worms and other diseases, increased by 11% in 2016. Table 4 also shows significant differences in two animal health indicators between the treatment and the control group in 2016. Expenditures for veterinary inputs are lower and the value of animal outputs is higher for participants. These results suggest that TRYRAC intervention is positively correlated with increased knowledge and improved practices and health.

Table 4: Knowledge, practices and animal health

Indicator	2013			2016		
	Treated	Control	Diff.	Treated	Control	Diff.
Knowledge score	9.12 (7.15)	8.8 (8.77)	0.4	37 (15.50)	12.5 (15.36)	28***
Practice score	14.15 (8.97)	13.51 (10.82)	0.64	29 (12.88)	18 (19.57)	11***
Veterinary input cost PPP\$	21.91 (45.13)	22.67 (41.14)	0.76	2.41 (6.41)	4.81 (13.22)	2.40***
Total output value PPP\$	37.37 (61.75)	37.56 (65.17)	0.19	159.75 (405.40)	91.61 (269.70)	68.14***
Observations	214	229		214	229	

Note: Significance of differences was assessed by t-test. Standard deviation in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' calculations

Table 5 presents a comparison between welfare outcomes of TRYRAC treated and control groups before and after the intervention. Focusing on the baseline year first, we do not find significant differences between these groups. However, we find significant differences in the period after the intervention in terms of consumption, income and poverty reduction. More specifically, while consumption improved over time in both groups, the increase was significantly higher among participants (28% points). A closer look at total household income reveals that both participants and nonparticipants recorded a decrease over time. Participants recorded a drop of PPP\$ 37.27, while nonparticipants recorded a drop of PPP\$ 53.16. One possible explanation for the participants' lower drop in total income is that participation could have served as a smoothing mechanism by stabilizing livestock income, thereby reducing the total income shortfall.

Table 5: Welfare measures by treatment status

Indicator	2013				2016			
	Pooled	Treated	Control	Diff.	Pooled	Treated	Control	Diff.
Consumption per capita (PPP \$)	1004.68 (770.78)	1043.66 (764.05)	968.27 (776.91)	75.39	1260.10 (1533.3)	1442.87 (1843.8)	1089.31 (1149.4)	353**
Total HH income per capita (PPP \$)	772.55 (941.12)	845.73 (945.61)	704.16 (925.19)	-141.59	691.92 (736.03)	808.47 (708)	651 (742.41)	157**
Proportion of poor (< US\$ 1.90/day)	0.47 (0.49)	0.46 (0.50)	0.48 (0.50)	-0.02	0.48 (0.50)	0.42 (0.50)	0.53 (0.50)	-0.11**
Poverty gap (%)	0.15 (0.01)	0.16 (0)	0.15 (0)	0.01	0.17 (0.01)	0.15 (0)	0.18 (0)	-0.03
Poverty severity (%)	0.078 (0.005)	0.073 (0)	0.082 (0)	-0.09	0.096 (0.009)	0.090 (0)	0.101 (0)	-0.011
Vulnerability (%)	0.25 (0.43)	0.25 (0.44)	0.26 (0.43)	-0.01	0.28 (0.42)	0.22 (0.43)	0.25 (0.42)	-0.03
Observations	443	214	229		443	214	229	

Note: Significance of differences was assessed by t-test. Standard deviations in brackets; Calculation of poverty indices based on the US\$ 1.90 PPP

Source: Authors' calculations

In terms of poverty and vulnerability, we found that approximately 47% of our sample respondents were living below the poverty line in 2013, whereas 48% were below the poverty line in 2016. The poverty headcount decreased by 4% points for participants and increased by 5% points for nonparticipants over time. Additionally, the poverty gap decreased by 1% points among participants and increased by 3% points among nonparticipants. Approximately 30% of all respondents in our sample were vulnerable to poverty. However, this figure decreased for participants by 3% points, while it decreased for nonparticipants by 1% point in 2016. These observations point to three important inferences. First, poverty remains high over time in the total sample. Second, there are slight improvements in the static and dynamic poverty indicators for TRYRAC participants. Thus, TRYRAC interventions could have an impact on reducing poverty by improving consumption and smoothing total income.

In summary, the unconditional summary statistics presented above suggest that the TRYRAC interventions improved participants' knowledge, practices and welfare outcomes relative to nonparticipants'. However, these findings could be driven by other exogenous factors because program participation is likely to be endogenous. In the next section, we present the results of

the multivariate econometric estimation strategies to net out the impact of TRYRAC while controlling for different estimation concerns, as discussed in the methods section.

5. Results and discussion

According to our impact pathway layout, we first investigate the impact of the TRYRAC intervention on cattle farmers' knowledge and practices and animals' health. Second, we analyze whether improvements in outcomes from the first step trigger improvements in households' welfare indicators.

5.1. *Impact of interventions on farmers' knowledge and practices and animals' health*

Table 6 shows the average effects of the treatment (ATT) on knowledge, practices and animal health for the different estimation strategies introduced. Columns 1 and 2 show the DD-fixed effects estimation with and without controls, respectively. Column 3 presents the fixed-effects instrumental variable estimates.

Our results generally show a significant positive impact of TRYRAC interventions, as the knowledge and adoption of improved practices to enhance livestock health improved among treated households across all the model specification. Specifically, Table 6 shows that TRYRAC intervention improved the AAT knowledge of participating households by approximately 30%. The impact coefficients do not significantly differ when we add time-varying household and village characteristics in column 2, an indication that the correlation between treatment and covariates is low. IV-FE returns similar results as the DD-FE estimates. These findings are similar to the results of [Liebenehm et al. \(2011a\)](#), who report knowledge increases for cattle farmers in Mali and Burkina Faso after veterinary interventions were introduced.

In the next step, we show whether farmers apply the observed improved knowledge in their disease management decisions. We report the effect of knowledge score on improved practices that households adopted for AAT management (Table 6). Our conservative model results show that knowledge gained from the intervention increases the adoption of improved disease management practices by approximately 9%. In terms of numbers, this result means that treated households adopted and implemented 3 additional improved practices as a result of the gained knowledge. For every 10% increase in knowledge score, farmers adopted 1 improved practice.

Given that TRYRAC interventions improved farmers' knowledge and use of improved practices in managing diseases, we would expect these to translate into improvements in animal health. To test this hypothesis, we investigate the impact of TRYRAC interventions on AAT prevalence, veterinary input expenditures and productivity, measured as income from livestock output (milk, draft, and manure). On average, the results show a reduction in the number of sick animals (3 animals on average) for treated households herds compared to the control households. Although this reduction is modest, the possible positive spillover effect for animals in the control villages could explain this result. This has the possibility of improving their health outcome. Cattle in the study area are kept in an open range system, exposing herds in the treated and control villages to both positive and negative spillover effects. For example, improved disease management practices resulting from the intervention in the treated villages may also lead to a reduction in the tsetse population and disease prevalence, causing a positive spillover effect benefit for the herds of nonparticipating households. However, a negative implication explained by the free-rider effect of nonparticipants' herds causing reinvasion and coinfections may reduce the estimated welfare benefits accruing to treated herds. That said, we expect the positive benefit to outweigh the negative effect. To this end, we compare the health outcome of herd and find that health status of all herds (both treated and control households) in the post-intervention period generally improved, an indication of a higher spillover effect.

In line with the stated impact path identified in this study, improved animal health is also expected to result in higher productivity and a reduction in input or production costs, which is mainly veterinary costs (trypanocides, other medications and service charges). Specifically, we investigate the impact of the interventions in reducing veterinary input costs through a reduced need for trypanocide, insecticides and deworming drugs. Table 6 shows that TRYRAC reduced veterinary input expenditures by approximately PPP\$ 8.62 to PPP\$ 12.63 (1,950 CFAF to 2,850 CFAF), depending on the estimation regime. This figure is equivalent to US\$3–5.5 per annum per cattle head and translates to a total savings of approximately US\$27–50 per herd (with a minimum herd size of 9) per annum.

Table 6: Impact on knowledge, practices, and disease prevalence

Outcome Variable	Basic DID (1)	Full MLS DID (2)	FE-IV (5)
Knowledge score	0.302*** (0.026)	0.302*** (0.038)	0.327*** (0.027)
Practices score	0.095*** (0.021)	0.092*** (0.025)	0.100*** (0.021)
AAT Prevalence	-2.885*** (0.812)	-3.061*** (0.786)	-3.302*** (0.555)
Veterinary input cost (PPP\$)	-8.620** (4.209)	-10.275** (4.031)	-12.633** (4.967)
Controls	No	Yes	Yes
Fixed effects	Yes	Yes	Yes
Observations	886	886	886

Note: Clustered robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; standard deviations in brackets; AES = adult equivalent scale; PPP = purchasing power parity; Controls: age, household size, dependency ratio, education of household head, social network dummy, shocks, risks, and farm size.

Source: Authors' calculations

5.2. *Impact of interventions on farmers' income and consumption*

Table 7 presents the results for TRYRAC welfare effects in terms of consumption per capita and income from cattle production. In terms of income, we found that improved cattle health has resulted in higher productivity, which leads to an increase in net income from cattle output, such as milk, traction and manure. Net income from the cattle products of the treated households increased on average between 16% and 84% more than the control households in the period. This result indicates that with good management practices, cattle's contribution to household income could double relative to the current figures.

In terms of welfare impacts at the household level, the results show a significant positive effect on total household income per capita for the treated. We find an income increase of between 29% and 47% for intervention participants. Although this figure may seem to represent a large jump in household income, this is intuitively consistent for two possible reasons. First, there

are large positive effects from reducing the veterinary expenses (production costs) and increasing the livestock productivity (increasing incomes) of the treated households. Second, livestock contributes a greater proportion of direct total household income (Table 3). Intuitively, better livestock management results in fewer losses, with increased productivity to improve overall income. In terms of consumption, we did not find any significant results for the treated households, although there is an increase in the consumption outcomes for the treated households in the post-intervention period. For example, a simple comparison of treated and control households show that consumption increased on average by PPP\$ 337.89 and PPP\$93.89, respectively, after the treatment period. Numerous reasons may be given for the observed result. The positive spillover of the treatment on the control groups leads to increased consumption outcomes, which effectively absorbs the treatment effects on the treated. Additionally, the per capita consumption of households is typically low; therefore, there will need to be a more than proportionate increase in consumption expenditure for any statistical significance to be observed.

The foregoing results give credence to the fact that improved cattle health translates into higher livestock productivity (livestock net income), household income and consumption per capita. In the following, we report the impacts of the intervention on stochastic poverty and vulnerability to poverty as a forward-looking welfare indicator for the treated household.

Table 7: Impact of TRYRAC on household welfare

Outcome Variable	Basic DID (1)	Full MLS DID (2)	FE-IV (3)
Net livestock income (log ⁷)	1.843*** (0.628)	1.520** (0.651)	1.16* (0.678)
Total net income per capita (log)	0.297* (0.160)	0.448** (0.146)	0.512*** (0.152)
Consumption per capita (AES) (PPP\$)	278.170* (162.444)	242.002 (149.762)	206.202 (166.434)
Controls	No	Yes	Yes
Fixed effects	Yes	Yes	Yes
Observations	886	886	886

NB: Clustered robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; standard deviations in brackets; AES = adult equivalent scale; PPP = purchasing power parity; Controls: age, household size, dependency ratio, education of household head, social network dummy, shocks, risks, and farm size.

Source: Authors' calculations

5.3. *Impact on poverty and vulnerability*

Finally, Table 8 presents the impact of interventions on poverty and vulnerability⁸. In column 1, we report the impact of the interventions on reducing the poverty headcount ratio. Our results show that TRYRAC reduced the poverty head count ratio by approximately 12% points, which is statistically significant at the 10% level. This result may indicate that TRYRAC interventions that have triggered improvements in a household's consumption and net income also translate into a reduction in poverty.

In column 2, we report the impact of TRYRAC on vulnerability to poverty in the future. Our findings show that participating households were 7% less likely than nonparticipants to be vulnerable to future poverty. Similar to the argument above, this result suggests that TRYRAC interventions contributed to smoothing income and consumption and thus reduced the likelihood of participating households falling below the poverty line in the future. The result is

⁷ To linearize the data, we took the log of the veterinary expenditure and net household income because the original data were skewed with many outliers. Although the utmost care was taken to clean the data of extreme outliers, we observed that some remained in the data.

⁸ For brevity, the FGLS procedure predicting the future log-consumption and consumption variance for the estimation of vulnerability are not reported. It can be provided by authors upon request.

line with the findings of [Khonje et al. \(2018\)](#), who report the significant welfare impact of technology adoption in eastern Zambia and the recent study of [Parvathi \(2018\)](#), who finds that improved livestock production can improve food security outcomes among livestock farmers.

Table 8: Impact on poverty head count and vulnerability to poverty

	Poverty headcount (Fixed effects)	Vulnerability (Fixed effects)
	(1)	(2)
TRYRAC (Participation)	-0.118*	-0.072**
	(0.064)	(0.037)
Year (1=2016)	-0.036	-0.008
	(0.080)	(0.057)
Constant	0.918**	0.754***
	(0.438)	(0.224)
Controls	Yes	Yes
Observations	886	886

Note: Clustered standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Controls: age, age squared, household size, dependency ratio, education of household head, social network dummy, shocks, risks, and farm size

Source: Authors' calculations

6. Conclusions and policy implications

The role of livestock in improving the livelihoods of rural households remains critical in rural SSA, where credit, formal employment and other factor markets are highly imperfect or absent. Cattle in particular have the potential to improve household livelihoods, thereby reducing the poverty and consumption volatility that tend to make households vulnerable to both stochastic and structural poverty. However, the negative effects of livestock diseases, such as AAT, have dwarfed this potential. It is estimated that AAT affects an area of approximately 10 million km², causing the death of approximately 3 million cattle annually in SSA. The use of chemotherapy remains the most common control method used by livestock farmers to manage AAT.

However, the upsurge in resistance to trypanocides and other unsustainable disease management practices makes control of the disease elusive.

Using a balanced household panel data set from Togo, this paper investigated the impact of veterinary interventions launched within the scope of the EU-funded TRYRAC project on small-holder welfare in SSA. We discuss the linkage between knowledge gain and the adoption of livestock husbandry practices for disease prevention and management and how these improvements in herd management and health may translate into measurable welfare effects at

the household level. We employed different econometric estimation strategies to control for selection bias and program endogeneity that are likely to arise as a result of the nonrandomization of program participation. We specifically exploit the exogenous randomization of the intervention villages to implement a difference-in-difference (DD), the instrument variable fixed-effects and the propensity score matching (PSM) estimation strategies.

We find results that are robust across all estimation strategies employed. Specifically, the results show a positive impact of TRYRAC interventions on improving knowledge that remains significant and robust across all model specifications. Specifically, we show that treated households had an increase in knowledge score of approximately 30% compared to the control group because of their treatment status. This resulted in increased adoption of improved livestock management practices. For example, the results show that for every 10% increase in knowledge, participants adopted 3 more improved cattle husbandry practices. We also found that the adoption of improved practices resulted in a drop in AAT infections. Fewer AAT infections lead to increases in productivity by between 64–95% in terms of income. This further translates to a savings in veterinary costs of US\$3–5.5 per cattle head per annum, which translates to an annual savings of approximately US\$27–50 per herd for the average herd size in our sample. In terms of household welfare, we found that the interventions improved household income per capita by between 27% and 47%. We also found that this resulted in increased consumption per capita expenditure of between PPP\$ 250 and PPP\$ 290 and reduced poverty and vulnerability by 12% and 7%, respectively. Thus, the overall conclusion of this study points to the important role of interventions targeted at improving the health of livestock and improving rural livelihoods in SSA.

Based on our analysis, we submit the following policy recommendations. First, the case of TRYRAC shows the effectiveness of well-planned extension programs that include radio, market and village outreach programs to increase dissemination and increase the knowledge of the target group. To scale up technology adoption, there should be increased farmer and local partner participation in the technology dissemination chain. Second, ownership of farm implements such as animal-drawn plows should be encouraged among cattle farmers by removing the bottlenecks and bureaucracy in access to credit. Farmers could also be helped to form cooperatives to operate animal-drawn machinery pools. This step would increase household income and improve crop production, which are the key determinants of rural poverty and vulnerability in rural SSA.

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Table A1: Results of Results of matching algorithms

Outcome variable	Matching Algorithm	ATT	Robust AI standard errors	z-statistic
Knowledge score	PSM	0.289***	0.022	12.69
	NNM	0.297***	0.217	13.66
Practices score	PSM	0.080***	0.019	4.22
	NNM	0.088***	0.016	5.39
AAT prevalence	PSM	-2.070***	0.383	-5.39
	NNM	-2.200***	0.346	-6.35
Livestock income (log)	PSM	1.036	0.749	1.38
	NNM	1.516**	0.472	3.21
Log total income (PPP\$)	PSM	0.431**	0.141	3.06
	NNM	0.404**	0.124	3.25
Consumption per capita (adult equivalent scale)	PSM	440.94**	136.80	3.22
	NNM	447.16**	144.07	3.29

Note: PSM, matching on single propensity score, NNM, nearest neighbor matching without replacement, *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' calculations

Figure A1: Propensity scores distribution of treated and control household using baseline observables