Does Village Chickens Vaccination Raise Farmers' Income? Evidence from Rural Mozambique

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Abstract: This paper assesses the impact of chicken vaccination on farmers' income. A dynamic simulation model, VIPOSIM, combined with benefit-cost techniques, was used ensuring that both, the dynamic aspects of village poultry production system and selection bias are addressed. The findings of this study reveal that, in general, Newcastle Disease (ND) control results in a considerable increase in farmers' income. Economic profitability is not the underlying factor for low rates of chicken vaccination. To address adequately the adoption of ND control technology, the government should concentrate efforts on the strategies of extension and distribution of the vaccine.

Keywords: benefit-cost analysis; simulation model; Newcastle disease; economic impact.

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Does Village Chickens Vaccination Raise Farmers' Income? Evidence from Rural Mozambique

Despite great advances made towards reduction of poverty and malnutrition in the last two decades, many people remain poor and malnourished in Mozambique. Recent poverty estimates show that out of Mozambique's almost 21.5 million people in 2008/09, nearly 12 million lived below the national poverty line and, about 46% of children less than 60 months were stunted (MPD/DNEAP, 2010). The incidence of poverty and malnourishment is critically higher in rural areas, where 70% of households live and virtually all of them (96%) are engaged in agriculture (MPD/DNEAP, 2010). Clearly, the success in meeting economic growth and development goals requires serious investment and commitment oriented towards increasing agricultural productivity. The livestock sector is one of the key sectors to tackle poverty and food insecurity. Livestock increases and diversifies income, thereby reducing risk and vulnerability, mainly in places with limited potential for crop production (World Bank, 2006; Branckaert and Guèye, 1999).

Among the livestock species, chicken is the most significant in terms of level of ownership, access to animal protein, and the potential for earning cash income (SANDCP, 2005). In Mozambique, about 58% of rural households raise chickens (TIA, 2008). Rather than caged, large-scale poultry production, smallholders have "village poultry" that is generally owned and managed by rural poor, usually women. Village poultry plays a vital role in the improvement of nutritional status and income. This is the easiest specie to raise for sale and home consumption and, represents a global asset for many millions who live below the poverty line (Copland and Alders, 2005). Village chicken provide the owners with a form of savings that can help meeting essential family expenses, such as medicines, clothing and school fees. Families can also increase their income by taking advantage of seasonal peaks in poultry demand, such as at religious festivals or celebrations (Johnston and Cumming, 1991). Village chicken provide scarce animal protein, accounting for about 20% of protein consumed in developing countries (Jensen and Dolberg, 2003). The role of chickens is particularly relevant in the nutritional status and income of households with disabled, elderly members or lack of able-bodied workers due to war or HIV/AIDS (Copland and Alders, 2005).

However, village chicken production has been severely constrained by ND. About 42% of rural Mozambican households who raised chicken during 2007/2008 cropping season lost some of their chickens due to disease. ND accounts for about 50% to 100% of annual deaths of village chicken (MADER, 2005; MADER, 2004; Bangnol, 2001), increasing farmers' vulnerability to food insecurity and malnutrition. ND is particularly devastating for smallholder farmers who usually have limited means of protecting their flocks. It is commonly recognized that little progress could be made in the village poultry industry unless ND is controlled. Continual vaccination of chicken currently offers the only effective way of controlling ND (Udo et al., 2006; Alders and Spradbrow, 2001).

In Mozambique, both the government and Non-Governmental Organizations (NGO) have been promoting the use of the I-2 vaccine to control ND in the smallholder farming sector. I-2 has been locally produced since 1999, and its effectiveness and suitability to smallholder farmers is well documented (World Bank, 2006; Alders and

Spradbrow, 2001). Yet, the level of chicken vaccination against ND is still very low; only 4% of households who raise chickens vaccinate their chickens against ND (TIA, 2008).

While efforts to expand the coverage of vaccination are of vital importance to increase vaccine adoption in the long-term, empirical evidence showing that chicken vaccination actually raises farmers' income is equally important. Even though the profitability of an agricultural technology is not a sufficient condition, it is a necessary condition for technology adoption in the long-term (Ernst et al., 1994). Nevertheless, much less attention has been given to assess the economic returns of animal health interventions. Most impact assessment studies undertaken in developing countries have focused on assessing the profitability of crop-related technology (McSween et al. 2006; Bellon et al. 2005; Marasas et al. 2004; Howard et al., 2003; Oehmke and Crawford, 1996).

Woolcock et al. (2004) studied the impact of ND vaccination on household welfare in Mozambique. However, by using a static poultry model, they did not take into account the dynamic aspects of village poultry production systems. Village poultry production systems are complex, thus their studies require insight in the dynamics of the production system (Asgedom, 2007; Udo et al. 2006). These authors argue that temporal variation in village poultry is a result of interaction of several factors, including flock mortality, egg production, reproduction, and bird and egg off-takes. Hence, the measurement of the impacts of interventions in this complex and dynamic system requires research tools that integrate the diverse processes and management options involved.

In this paper, the benefits of ND control at the farm-level are estimated from data obtained through farmers' surveys and interviews in combination with parameters derived from empirical literature. By using VIPOSIM, a dynamic simulation model adapted from Asgedom (2007), this study incorporates the dynamic aspects of village poultry production system in the estimation of the impact of chicken vaccination at farm-level. To guarantee robustness of the results, both stochastic and deterministic approaches are considered in the analysis.

Empirical approach

Choice of site and data sources

This study used both primary and secondary data. The primary data were collected in Chibuto district, where chicken vaccination has been promoted by the government and NGOs since 1999. Chibuto is one of the major livestock producing districts in the country, with a well-functioning vaccination program. Three sources of primary data were used: a formal household survey, key informants interviews using non-structured questionnaire, and semi-structured farmers' focus group discussions. Secondary data comprised the Agricultural National Survey (commonly known as TIA, Trabalho de Inquérito Agrícola), information from stakeholders involved in the ND control program, and diverse literature.

The formal household survey was conducted in four randomly selected villages, in July of 2007. A multi-stage random sampling procedure was used to select 226 households who raise village chickens. In each selected village, households were selected proportionally by random sampling in two groups, the participants and non-participants in the vaccination program, reaching a total of 127 and 95 households, respectively. The survey collected a broad range of socio-economic aspects of the households, such as demographics, asset ownership, chicken production systems, marketing, production constraints, cost of the vaccine, and farmers' perceptions of the usefulness of the vaccine.

The semi-structured farmers' focus group discussions were carried out in August of 2008 in the same villages where the formal survey was conducted. The goal of those discussions was to gather relevant information for modeling of the village poultry production system. This information included the village chicken life cycle, growth trajectory, off-take, likelihood of ND occurrence in the region, and dynamics of flock size, management and disease incidence.

Conceptual framework and estimation techniques

Animal disease represents a negative input in the production process; it causes direct economic losses for the producer and a potential loss of value in the view of the consumers (Otte and Chilonda, 2000). It is commonly agreed that the effects of animal diseases in a given production system is a reduction of the efficiency with which inputs/resources are converted into outputs/products, decreasing productivity (Bennett, 2003; FAO, 2001; Otte and Chilonda, 2000). Disease impacts are generally easy to identify but may be difficult to quantify (Pritchett et al., 2005), so are the estimations of the impacts of disease control.

The measurement of economic benefits of a technology consists of comparing the benefits with technology use to a counterfactual that represents what would have occurred without the technology, the "with" and "without" situations. The difference is the incremental net benefit due to the technology (Alston et al., 1998; Gittinger, 1982). However, counterfactual situation is usually unobservable, that is, it is not possible to observe the outcome variables of the adopters in the case they did not adopt.

This problem is usually addressed by randomly assigning adoption and control status which assures that the outcome variables observed on the non-adopters are statistically representative of what would have occurred to the adopters if they did not adopt (Amare et al., 2012). Yet, this may raise the problem of endogenous program placement since the adopters and non-adopters may be systematically different.

Propensity score matching is a widely used econometric technique, which corrects for potential bias in the estimation of the impact of technology adoption on household welfare outcomes. This technique compares the difference between the outcome variables of adopters and non-adopters with similar inherent characteristics. However, propensity score matching cannot correct unobservable bias because it only controls for observed variables (Amare et al., 2012).

Simulation models are an alternative approach for measurement of the impacts of interventions that can address selection bias problem. By integrating the different processes and management options involved in the complex and dynamic system, this approach provides insights in the dynamics of the system (Asgedom 2007; Udo et al.

2006). Modeling can be used to address selection bias by incorporating probabilistic effects or by using statistically representative input variables in the analysis.

In this study, modeling approach combined with benefit-cost method is used to estimate the impact of technology adoption on household income. To address the differences of the dynamics of poultry production systems resulting from vaccination, the two situations, the with control and without control, are simulated separately. However, all the input parameters incorporated in the model are the same in both situations, except the ND mortality levels and the cost of the ND control. This ensures that only the impact of ND control is captured in the analysis.

Indicators of economic efficiency, such as Net Present Value (NPV) and Internal Rate of Return (IRR) can be estimated to assess the impact of vaccination. For this specific study, however, these measures may not reflect the decision behavior of the farmers in the short-term. Costs of chicken vaccination at farm-level do not change considerably from year to year. A farmer with losses in one year may abandon poultry production and invest in other activities instead. Thus, the annual net benefits of vaccination are used as the measures of the impact of chicken vaccination. The results at farm-level are presented in terms of annualized total present value of the net benefits, since the model was built to simulate 12 seasons (three years) at once.

Description of the simulation model

In this study, an adapted VIPOSIM, the **VI**llage **PO**ultry **SI**mulation **M**odel, is used in the measurement of the annual incremental benefits resulting from chicken vaccination at farm-level. This is a dynamic simulation model used by Asgedom (2007) to assess the impacts of different management strategies in a poultry production system. VIPOSIM was developed by a team from Wageningen University, in the Netherlands, and validated with data from Tigray, Ethiopia (Asgedom 2007). In this study it is adapted to suit the Mozambican context.

VIPOSIM takes into account the complex and dynamic aspects of village poultry production system by incorporating six processes related to chicken production and management (flock off-take, egg production, egg loss, egg off-take and reproduction). This model performs calculations in time steps which represent reproduction cycles. Each step has a length of a season of 3 months and the maximum number of steps in the model is 12, which corresponds to a period of three years (Asgedom, 2007). It was programmed in Microsoft Excel® and integrates quantitative relationships of various elements of the system in a series of mathematical equations.

In the VIPOSIM model, a flock is categorized in five categories of chickens according to age and gender: i) the chicks group includes all chickens with age up to three months; ii) cockerels are male chickens older than three months but not yet adult; iii) pullets are female chickens older than three months but not yet adult; iv) hens are female adult chickens; and v) cocks are male adult chickens. According to the farmers in Chibuto district, chickens are adult at the age of six months. Some of the input parameters are expected to vary across chicken categories, such as the flock size, mortality rate due to disease and/or predation, and bird off-take.

Figure 1 shows the sequence of the events in VIPOSIM. The broken arrows indicate inputs and outputs variables. The input variables in VIPOSIM include chicken production and management parameters such as initial size and composition of the flock, mortality rates, bird sales and consumption rates, egg production, reproduction parameters (incubation and hatching), egg sales, egg loss, egg consumption rates, and bird off-take limits. These variables are believed to be related to agro ecology and husbandry conditions, and they differ across the seasons. The economic parameters such as prices of birds and eggs and costs of production are also input variables in the model. VIPOSIM categorizes costs into costs of labor and costs of intervention.

As the output, the model gives the numbers and values of bird off-take and egg off-take, and the final composition of the flock for each season during the three-year period of simulation. This model has the advantage of allowing for incorporation of random phenomena in the analysis. Also, it can be easily transformed into a deterministic model by setting all the standard deviations inputs to zero.

Some considerations in modeling the benefits of vaccination

Various changes were made in order to accommodate the model to the current context of the study taking into account the limitations of VIPOSIM, the objective of the research, and data availability. The majority of the changes were based on location-specific information and knowledge of village chicken production systems in Mozambique.

The VIPOSIM model requires information on production and utilization, some of which was not available for Mozambique. In the case of insufficient information, the original parameters developed for the VIPOSIM model were used, based on the assumption that production and utilization parameters are similar for village chickens in Mozambique or elsewhere. For example, collected data on parameters such as flock size, mortality and bird off-take were not disaggregated by categories of chickens. Thus, the parameters needed for each category were generated based on general information collected and the relationship between the parameters across the categories in the default input data of VIPOSIM, data used by Asgedom (2007) to validate the model.

In addition, the design of VIPOSIM categorizes the input parameters of mortality in three groups: mortality due to the disease, mortality due to predation, and mortality due to other reasons. But, given the nature of the collected data and the objectives of the study, only two categories of mortality parameters were defined: mortality due to ND or mortality due to other reasons[1]. Also, VIPOSIM categorizes the parameters for bird and eggs off-take into two groups: sales and home consumption. In this study, bird off-take parameters were treated as one broad category because in Chibuto typically there are no off-take of chicks or sale of village chicken eggs.

Since the use of production inputs in village poultry production is very low in the rural Mozambique context, only the cost of vaccination was included in the simulations as an additional cost of chicken vaccination. It was assumed that the additional costs of labor or other inputs resulting from chicken vaccination were negligible.

[1] This second category combines mortality due to predation and other causes as designed in VIPOSIM

Similarly to the original model, the model takes into account that some input parameters vary across the seasons within a year. The variation is based on the farmers' perceptions of the best and worst periods and the range of values provided. For instance, in Chibuto farmers only reported outbreaks of ND in the last two quarters of the year. Hence, inputs parameters of ND mortality were only incorporated for the third and fourth quarters of the year; in the other quarters, the mortality due to ND was assumed to be negligible.

The seasonality of losses due to predations and other causes was also reported in the study area. According to the farmers, during the hungry season (wet season: from October to February) there is lack of animal feed. Thus, chicken tend to go far from the houses scavenging for food, becoming more vulnerable to predators than in the dry season. Additionally, the relatively denser vegetation in the villages during the wet season harbors predators. The food scarcity is also associated with higher occurrence of chicken theft. Hence, the last quarter of the year tends to have the highest rates of bird losses due to predations and other causes, whereas the second quarter of the year has the lowest rates. The other two quarters have intermediary values.

Although VIPOSIM was designed to generate both direct (bird and eggs off-takes) and indirect benefits (manure and the value of immediate availability of birds for cash and social needs), only direct benefits resulting from avoidance of bird loss were considered in this study. The direct benefits of I-2 vaccine use could be in terms of an improved quality of chickens[2], increased flock size and/or increased off-takes. Due to the low level of quality differentiation in the market for village chickens in Mozambique, and due to the difficulties in getting data on quality improvement resulting from vaccination, only direct benefits related to increased off-take of chickens and eggs are considered. For instance, the increase in egg productivity due to vaccination could be addressed by incorporating higher reproduction parameters in the "with-control" situation than in the "without-control" situation. But, no information on the increase of the clutch due to ND control is available. The additional indirect benefits such as the value of manure, social roles of chickens, among others, that may increase due to vaccination, were not estimated in the study, in part because it is difficult to assign a monetary value to these benefits.

The flock size is expected to have a positive effect on the size of the benefits of vaccination at farm-level. Given level of incidence of ND in a region, the rate of mortality due to ND is expected to be relatively higher in households with bigger flocks than in the ones with smaller flocks. This expectation is related to the fact that ND is transmitted through physical contact between chickens, and the bigger the flock size, the higher is the contact between chickens, and the higher are the chances of infecting each other. Thus, the size of benefits of vaccination might depend on the size of flock. The bigger the flock, the larger is the number of chickens expected to be saved by vaccination and, the bigger are the expected benefits of vaccination. Hence, in the estimation of overall benefits of ND control at farm-level when the flock size is not treated as random variable, there is a need to ensure that the initial flock size incorporated as an input in VIPOSIM is the typical flock size.

[2] In the presence of ND, chickens are less healthier, with less weight and there might be a dramatic drop in the number of eggs laid per clutch

Results of diagnostic analyses for both groups the participants and non-participants farmers in ND control program, the distribution of flock size is asymmetric (Figure 2). Therefore, the average flock size is not a typical flock size. To overcome this problem of asymmetric distribution, six categories of households were created based on the flock sizes and the proportion of each household category was estimated (Table 1). Then, a separate simulation was performed for each category of flock size to get the benefits at the category. Then, the overall benefit of ND control was estimated as the sum of the benefits of each category weighted by the respective frequency. This is one of the key innovations of this study.

Moreover, the rate of vaccination in the model is defined as the ratio between the numbers of chickens vaccinated and the size of the flock. However, estimation of the rate of vaccination at farm-level is not straightforward. It requires very detailed information on the flock size and numbers of chickens vaccinated in each campaign, and such data are hard to obtain. On the other hand, Mozambican farmers are likely to vaccinate less than 100% of their flocks because, among other reasons, it is difficult to catch all the chickens for vaccination due to the feral nature of village chickens. Survey data show that about 20% of the households, who vaccinate their chicken, did not vaccinate 100% of their flocks in the last vaccination. Not being able to catch all the chickens on the vaccination day was the main reason behind the partial vaccination for 90% of the households.

Nevertheless, estimation of the rate of vaccination at farm-level may not be a major concern when a large proportion of the flock is vaccinated because of the nature of the I-2 vaccine, which is composed by live virus that can be transmitted among the chickens in close contact. Hence, the I-2 vaccine can also protect some non-vaccinated chickens in close contact with vaccinated ones in the flock (Alders and Spradbrow, 2001). In addition, flock vaccination also provides protection for newly hatched chicks within the interval of three to four months after vaccination (Alders and Spradbrow, 2001). Therefore, the assumption of 100% vaccination at farm-level for "with-technology" situation is not likely to be critical, this assumption is used to simplify the analyses.

There is uncertainty attached to some of the relevant variables used for computation of the benefits at farm-level. One such variable is the observed without-control ND mortality, for which the information available in Mozambique is very limited. Therefore, both stochastic and deterministic approaches were considered in the analysis in order to ensure robustness of the results.

In the deterministic analysis, all the standard deviations in VIPOSIM were set to zero. Then, the sensitivity of the annual net benefits at farm-level to the assumptions about levels of ND mortality was evaluated to deal with the uncertainty involved[3]. Price sensitivity is even more important to evaluate because there might be price effects due to technology use. Therefore, it was evaluated how much the price of chickens can decrease without affecting the overall farm-level profitability of vaccination.

[3] About 20 scenarios of without-control ND mortality levels were defined (19 hypothetical scenarios plus the base scenario, defined by the data collected on ND incidence), varying from 5% to 95%, and their respective benefits estimated

In the stochastic analysis, the ND mortality rate was treated as a random variable in the modeling. Of note is that the stochastic component of VIPOSIM is very restrictive since it assumes that all the random parameters follow a normal distribution, which is not the case for the input parameters used in this study. The stochastic analysis was performed using the combination of @Risk software and VIPOSIM. This surmounts the restriction imposed by the normal distribution assumption in the design of VIPOSIM. The VIPOSIM model was set to deterministic mode, and @Risk software was used to generate the distribution of the benefits based on the best-fit probability distribution of data on ND mortality.

Estimating the benefits of chicken vaccination at farm-level

To estimate the benefits of chicken vaccination at the farm-level, the adapted VIPOSIM simulations (with modification previously described) were performed. For each scenario (based on the without-control ND mortality level) that was considered in the analyses, two simulations were performed. The first pertained to the "without-technology situation", in which the without-control ND mortality levels were incorporated. The other simulation was the "with-technology situation", where vaccination costs were incorporated and ND mortality rates were reduced to with-control levels. In the latter, the mortality due to ND of without-control situation was reduced by 80%, that is, about 20% of "without-control" ND mortality levels, based on the findings of the field trials in Mozambique (Dias et al., 2001).

The benefits of chicken vaccination at farm-level were determined by applying partial budgeting procedures to the simulations results. From the outputs of the simulations, the net benefits in each season for a given initial flock size category were computed as:

$$NB_i = B_i^{wi} - B_i^{no} - C_i \qquad (1)$$

where NB_i is the net benefits of ND control at farm-level of season i, in meticais (MZM, 1USD≅25MZM); B_i^{wi} are the benefits (the total values of off-take, in MZM) for the "with-control" situation in season i; B_i^{no} are the benefits (in MZM) for the "without-control" situation in season i; C_i are the additional costs related to technology use (cost of the vaccine) incurred in season i, in MZM.

From the net benefits determined for each season, and taking into account that the interest is compounded quarterly (based on the length of village chicken production season of about three months), the total present value for the whole period of three years for a given category of flock size was estimated using the equation (Hoy *et al*., 2001):

$$PV = \sum_{i=1}^{12} \frac{NB_i}{\left(1+\frac{r}{4}\right)^i} \quad (2)$$

where PV is the total present value of the net benefits for the three years of simulation, in MZM; NB_i is the net benefit in season i, in MZM; and r is the discount rate[4]. The farm-level annual net benefits for a given initial flock size category were estimated using the following formula (Ross et al., 2008):

$$ANB = PV * \left[\frac{1-\frac{1}{(1+r)^T}}{r}\right]^{-1} \quad (3)$$

where ANB is the annual net benefit in MZM; T is the number of years, T=3 based on the length of a simulation in VIPOSIM, which is three years period; and r is the discount rate. The overall annual net benefit of ND control at farm-level is given by:

$$VB = \sum_{i=1}^{6} ANB_i * \Pr_i \quad (4)$$

where VB is the overall annual net benefit per household in MZM; ANB_i is the annual net benefit for a category of flock size i, in MZM; and $\Pr_i$ is the proportion of households in the category of flock size i.

Results and discussion

The deterministic analyses for the base scenario[5], suggest that vaccination of chickens against ND using I-2 is financially profitable for the farmers. As shown in Table 2, regardless of the flock size category, the incremental annual net benefits at farm-level resulting from ND control are positive. This result is consistent with the findings of Asgedom (2007), who analyzed the impact of different interventions in a village poultry production system at farm-level and, found that ND control resulted in higher net returns than housing intervention in the Ethiopian context. These results are also in line with the findings from Udo et al. (2006) and Woolcock et al. (2004), who found that ND control has a positive effect on bird off-take, egg production, egg off-take and flock size.

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[4] The discount rate of five percent is used, based on personal communication with T. Walker, email to the authors on 11th May 2009, suggesting that this rate is increasingly used in the literature.

[5] The base scenario is given by primary data, where without-control ND mortality rate is about 63%; the prices of 22 MZM/bird for pullet/cockerels, 33 MZM/bird for adult bird, 1.3 MZM/egg, and a vaccination cost of 0.5MZM/bird.

In general, vaccination of chickens using the I-2 vaccine results in an increase of about 481 MZM (about 19 US dollars) in the household income. Chicken vaccination results in an increase of about 7% in the total household income[6]. This is a substantial improvement in rural households' incomes, considering that it requires very low investment. Farmers just need to invest about 47 MZM per year, which is less than 1% of the median total household income. Indeed, for each MZM invested in ND control, the household gets a return of about 10.3 MZM. This corresponds to an annual rate of return of 1030%, which is very high. Additional analysis of vaccine price variation, *ceteris paribus*, suggests that farmers' investments in vaccination will remain profitable as long as the cost of vaccine is less than 5.6 MZM/bird. This corresponds to more than 11 times the current cost of 0.5 MZM/bird.

It is, however, worthy noticing that benefits of vaccination estimated in this study, understate the actual benefits of vaccination. The design of VIPOSIM does not allow for the consideration of the potential positive externality resulting from protection of non-vaccinated chickens by horizontal transmission. The I-2 vaccine is based on live virus, and this can be transmitted horizontally from vaccinated to non-vaccinated chickens in close contact, protecting also non-vaccinated chickens.

While farmers' investments in the ND control are clearly profitable, cash investment in the vaccine may be a constraint for vaccine adoption by the poorest group of farmers. This investment corresponds to about 14% of their household income (Mather et al., 2008). Giving those farmers opportunities to pay for vaccination in chickens instead of cash, may be one way to overcome the problems of lack of cash for vaccine payments, especially because the vaccinators are one of the biggest poultry producers in the communities. Nevertheless, there are financial incentives for the farmers to invest in ND control, and farmers just need opportunities to realize the benefits. The success in increasing the rates of use of I-2 in the long term appears to depend on extension strategies and distribution of the vaccine to the final users.

Results of sensitivity analysis for a range of without-control mortality rates show that the annual incremental benefits at farm-level are sensitive to without-control mortality levels. As the overall level of without-control mortality increases, the overall incremental benefits also tend to increase (Figure 3). This is expected, since in places where the ND mortality rate is high the vaccine is expected to save more chickens than in places with a lower ND mortality rate. This suggests that in the process of expanding the vaccination program, priority should be given to areas where ND mortality rate is very high. However, for informed decision about the prioritization in the expansion of ND control program, information on the levels of ND prevalence across the country is relevant. Yet, this information is not available currently.

Detailed results (Table 3) reveal that the net benefits can even be negative for households with smaller flock size (0 to 10 birds) when the without-control mortality levels are very low. However, regardless of the flock size category, all farmers have positive returns whenever the levels of ND mortality rates are appreciable (at least 40%). Chicken vaccination result in additional income that will help to lift some of those

[6] This is based on Mather et al. (2008) estimates, who estimated the median net total rural income per adult equivalent in of about 1,723 MZM, which corresponds to the household income of about 6,892 MZM.

families above the poverty line, for the following reasons. First, chickens are usually the only liquid asset owned by the poorest farmers. Second, ND is endemic in Mozambique and causes severe losses annually. Third, a large percentage of the rural population is engaged in chicken production. This finding is in line with Walker et al. (2006) findings, which show that a 20% increase in chicken production could result in a 4% reduction in the severity of poverty. Yet, accurate estimates of how much the poverty indicators will fall because of ND control require precise data on the levels of ND prevalence across the country.

Results of the analysis of the net benefits as chicken prices are progressively reduced, *ceteris paribus,* show that the net benefits become zero only if the price is 9% of the original price used in the analysis; That is, the price can fall by as much as 90% without affecting the overall profitability of the vaccination. The profitability of ND control at the farm-level is not very sensitive to chicken price changes. Only in the extreme case of almost perfectly inelastic demand for village chickens, would the increase on the supply due to vaccination result in negative returns, but this is not likely.

Analysis of best-fit distribution using @risk software suggests that the triangular distribution best fits the ND mortality data. Stochastic analysis treating the ND mortality rates as a random variable show that there is a 90% probability that the values of the annual net benefits at farm-level fall between 248 and 543 MZM (Figure 4). This confidence interval covers the overall annual net benefit estimated using deterministic methodology. In addition, the results suggest that the most likely value of net benefits at farm-level is 483 MZM per year, which is close to 481 MZM (the value estimated in the deterministic approach). The results of the two approaches of estimation are robust.

Conclusions and policy implications

In Mozambique, village chicken production is severely constrained by ND; hence, promotion of chicken vaccination is a concerted effort towards achieving food security and poverty eradication. Despites the efforts by the government and NGO's in expanding the vaccine use, the level of chicken vaccination against ND is still very low. This calls for an assessment of the impact chicken vaccination, that will enable an identification of the shortfalls in vaccination program and plausible interventions in the future.

This paper assesses the impact of chicken vaccination on smallholder farmers' income. A dynamic simulation model, VIPOSIM, combined with benefit-cost techniques, was used, ensuring that both, the dynamic aspects of village poultry production system and selection bias are addressed. The results obtained using both deterministic and stochastic approaches are close, suggesting that the finding are robust.

The results of the analysis show that, in general, vaccination of village chicken against ND results in a considerable increase in farmers' household income. This supports the theory that vaccination has the potential to reduce absolute poverty and food insecurity. Economic profitability is not the underlying factor for low rates of chicken vaccination. To address the adoption of ND control effectively, the government should concentrate efforts on improving the strategies of extension and distribution of the vaccine. Further attention should be given to research on the prevalence ND across the country, as well as, to quantification of impact of ND control on poverty indicators.

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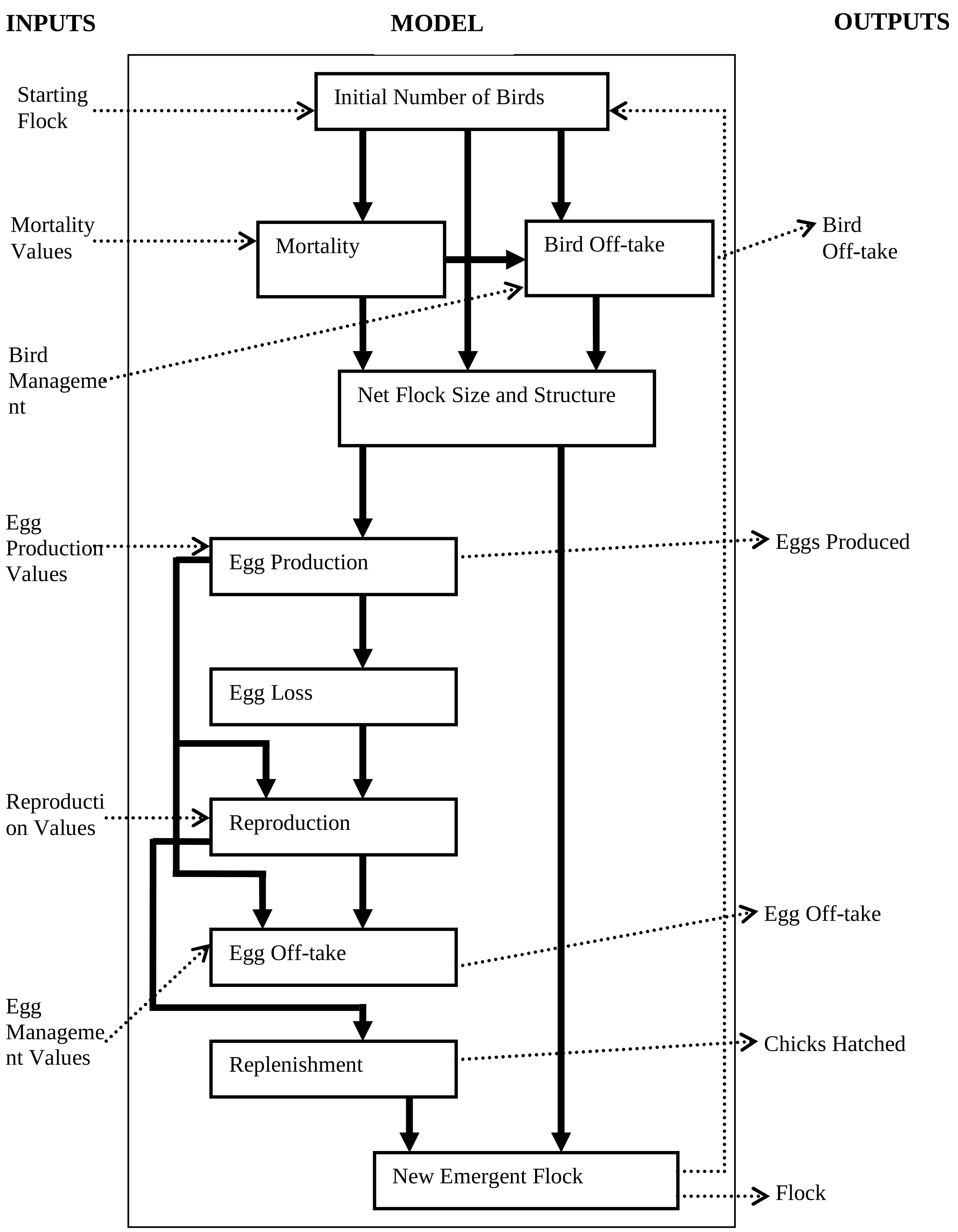

Figure 1: Schematic representation of sequences of events in the VIPOSIM for a reproduction season (adapted from Asgedom 2007).

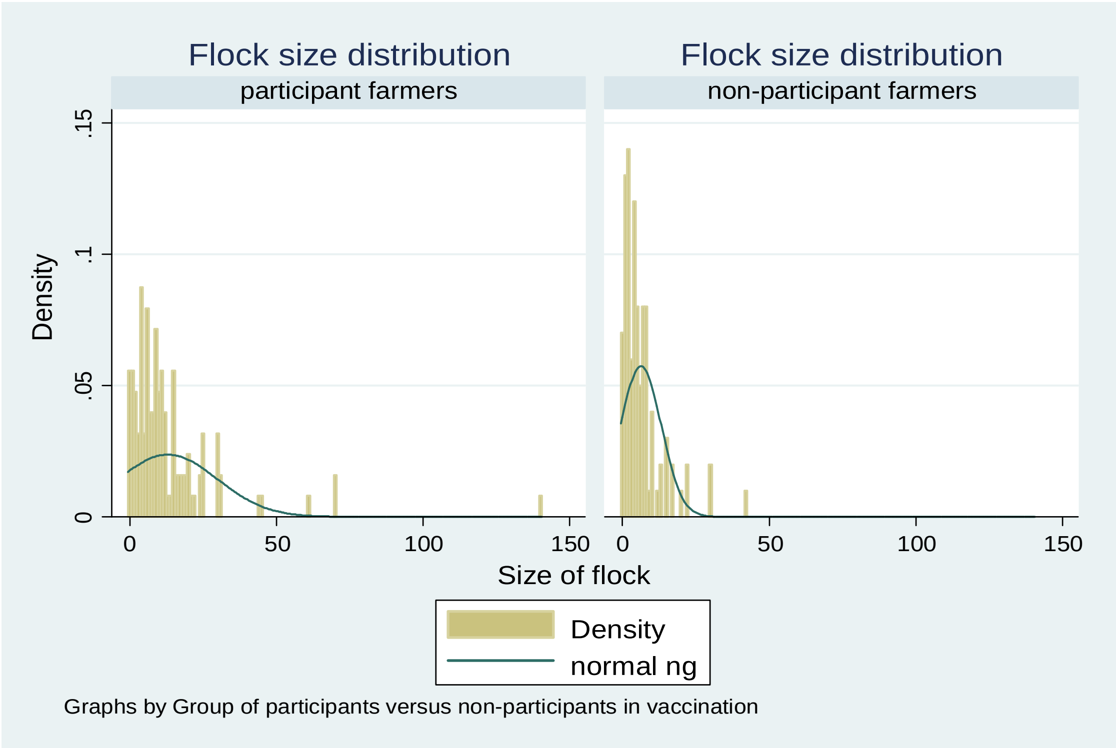

Figure 2: Distribution of flock size in Chibuto (source: household survey data)

Table 1: Households categories based on the flock size distribution in Chibuto

Size of Flock Category	Size of Flock Average	Size of Flock SD	Proportion of Households	Mortality Rates Level	Mortality Rates SD
Category 1 (0-5 Chickens)	2.4	1.6	44%	33%	28%
Category 2 (6-10 Chickens)	7.8	1.4	27%	80%	4%
Category 3 (11-15 Chickens)	13.0	1.7	12%	88%	2%
Category 4 (16-20 Chickens)	18.1	1.5	6%	92%	91%
Category 5 (21-25 Chickens)	23.5	1.6	4%	94%	<1%
Category 6 (26 or more Chickens)	41.0	15.5	6%	96%	1%

Data Source: household survey and focus group discussion

Table 2: Annual incremental benefits and costs of ND control at farm-level

Flock Size Category	Annual Net Benefits (MTN)	Annual Costs of Vaccination (MTN)
Category 1 (0-5 Chickens)	269	40
Category 2 (6-10 Chickens)	494	42
Category 3 (11-15 Chickens)	607	50
Category 4 (16-20 Chickens)	756	62
Category 5 (21-25 Chickens)	789	64
Category 6 (26 or more Chickens)	1179	93
Overall Benefit at Farm Level	**481**	47

Data Source: Estimations from VIPOSIM simulations

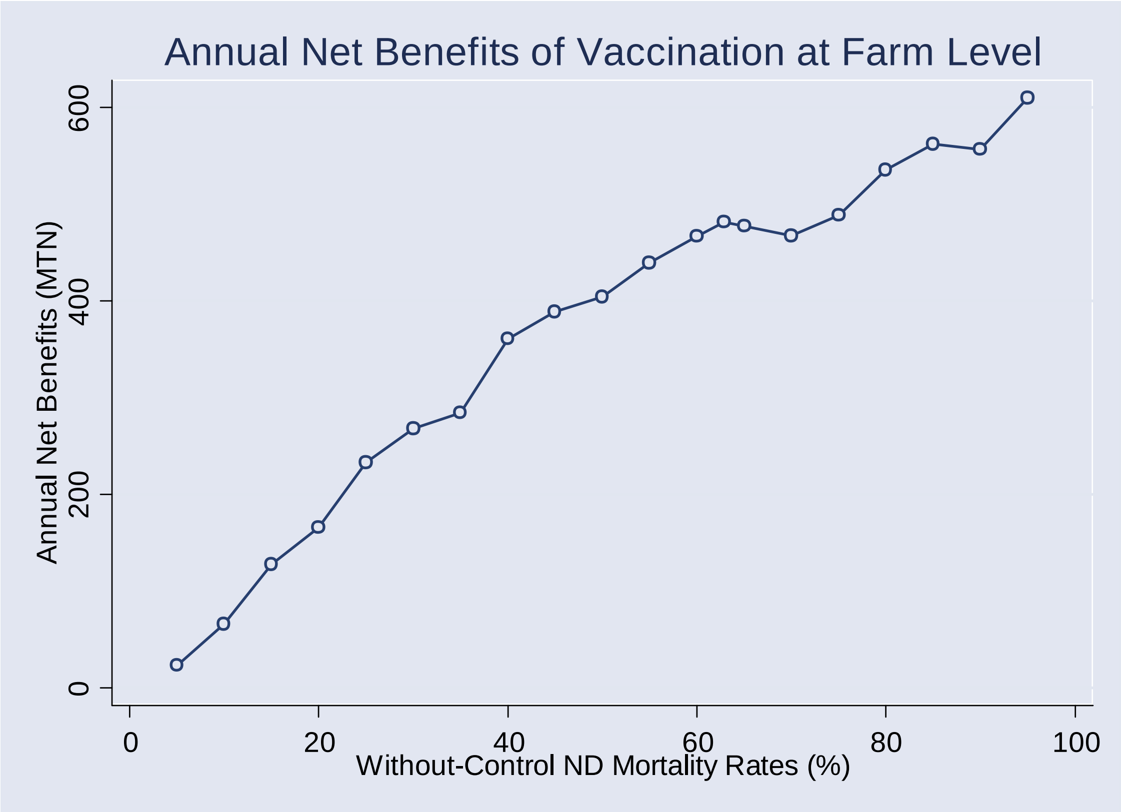

Figure 3: Sensitivity of farm-level benefits to without-control ND mortality levels (Data source: authors estimations)

Table 3: farm annual net benefits per flock category and ND mortality levels

Overall ND Mortality	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5	Cat 6	Overall
	Annual Net Benefits at 5% discount Rate (MZM)						
5%	(41)	(50)	(59)	88	346	664	23
10%	(41)	(50)	95	188	413	907	66
15%	(41)	(1)	246	400	595	1,053	128
20%	(41)	67	288	580	647	1,062	165
25%	(41)	222	453	616	717	1,063	233
30%	(40)	306	503	670	712	1,108	268
35%	(71)	282	607	803	882	1,235	284
40%	77	342	639	790	808	1,162	361
45%	124	369	645	782	807	1,163	389
50%	149	392	633	778	794	1,164	404
55%	181	469	625	776	797	1,188	439
60%	242	481	610	760	794	1,187	466
63%	269	494	608	758	793	1,187	481
65%	261	490	608	755	794	1,188	477
70%	227	510	603	752	791	1,200	467
75%	285	494	596	749	789	1,214	488
80%	371	528	591	745	797	1,230	535
85%	415	546	589	757	810	1,245	562
90%	390	553	599	767	823	1,259	556
95%	498	569	605	773	829	1,264	610

Source: Author Computations

Note: the values in brackets indicate negative values

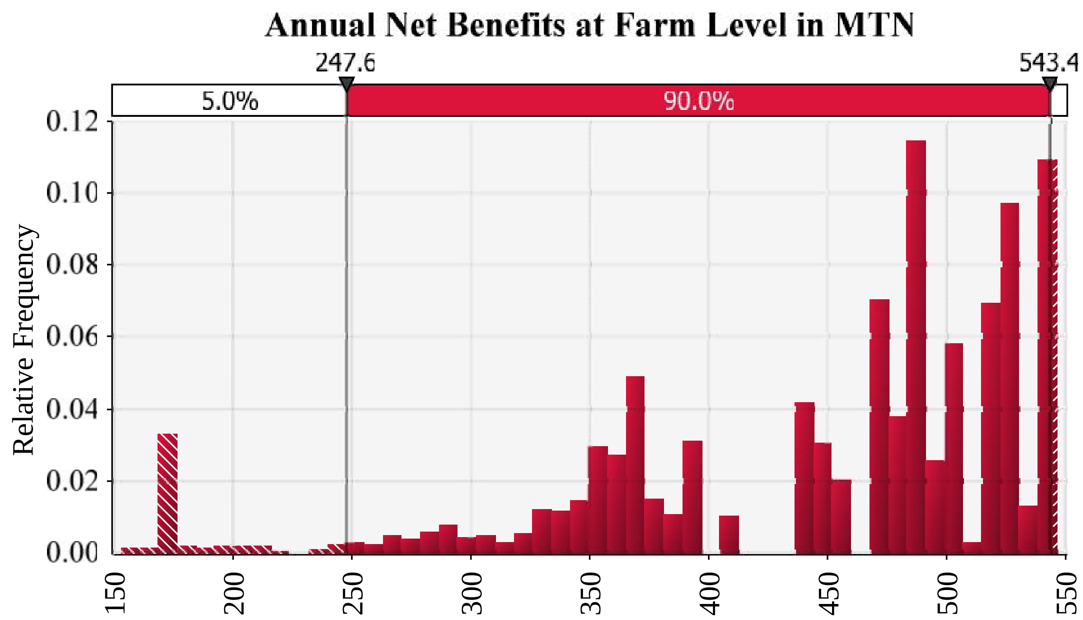

Figure 4: Distribution of benefits of vaccination (data source: authors' estimations)