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Investigating the Role of Poultry in Livelihoods and the Impact of Avian Flu on Livelihoods Outcomes in Africa

Evidence from Ethiopia, Ghana, Kenya, and Nigeria

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Contents

List of Tables

List of Figures

ABSTRACT

In this paper we investigate the role of poultry in households' livelihoods portfolios and the impact of supply-and-demand shocks that may be caused by highly pathogenic avian influenza (HPAI) on households' various livelihoods outcomes in four Sub-Saharan African (SSA) countries. The study countries include Ethiopia and Kenya in East Africa and Ghana and Nigeria in West Africa. These countries represent a spectrum of SSA countries regarding disease status, means of disease spread, and the role of the poultry sector in the economy. By using nationally representative household-level secondary data and discrete choice methods (probit and zero-inflated negative binomial models), we profile the household, farm, and regional characteristics of those households that are most likely to keep poultry and those households that are most likely to be engaged in intensive poultry production (that is, to keep larger household flocks). We estimate the ex ante impact of HPAI outbreaks and scares/threats on livelihoods outcomes by using the propensity score matching approach. The results of this study generate valuable information regarding the role of poultry in the livelihoods of small-scale poultry-producing households and the livelihoods impacts of HPAI-induced supply-and-demand shocks. Such information is critical for the design of targeted, and hence effective, HPAI control and mitigation policies.

Keywords: highly pathogenic avian influenza (HPAI), demand shock, supply shock, livelihoods, probit model, zero-inflated negative binomial model, propensity score matching

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1. INTRODUCTION

Poverty is both a cause and a consequence of the inability to cope with shocks. The poor are often considered more vulnerable to shocks because of the assumed lack of diversification in their income portfolio, asset portfolio, or both. In low-income countries of Sub-Saharan Africa (SSA), this vulnerability of the poor to various shocks is considered to be of the utmost importance for policy targeting. In the limited livelihoods diversification that poor households tend to have, livestock constitutes an important source of income and, in general, is the most important asset (Livestock in Development 1999; FAO 2002). The potential livelihoods impacts of a shock that affects the livestock sector—particularly the type of livestock kept by the poorest and most vulnerable populations (Sonaiya, Branckaert, and Gueye 1999)—should therefore be of paramount importance to policymakers.

This paper assesses the livelihoods impacts of a shock to the poultry sector in the form of a disease, specifically highly pathogenic avian influenza (HPAI), in four countries in SSA. The study countries include Ethiopia and Kenya in East Africa and Ghana and Nigeria in West Africa. The HPAI virus has been circulating in SSA since February 2006, when the first case was confirmed in the state of Kaduna, Nigeria. This virus has directly or indirectly affected the poultry sectors and overall economies of various countries in SSA. Benin, Burkina Faso, Cameroon, Djibouti, Ghana, Ivory Coast, Niger, Nigeria, Sudan, Togo, and Zimbabwe are among the countries affected directly through single or multiple outbreaks. SSA countries that have been indirectly affected include Ethiopia, Kenya, and South Africa, whose poultry sectors experienced scares and false alarms as a result of mass poultry loss to other diseases and HPAI threats due to outbreaks in neighboring countries.

In Beijing in 2006, amid fears of a human pandemic, multilateral donors and developed countries pledged substantial funding—US$1.9 billion—for HPAI prevention and control programs (World Bank 2006). Even though HPAI did not cause a human pandemic, 295 avian influenza– (A/(H5N1)) caused human deaths worldwide have been reported to the World Health Organization (WHO 2010) to date. A great majority of these human deaths (136) occurred in Indonesia, whereas 35 people died in the African continent (1 in Nigeria and 34 in Egypt) as a result of avian influenza (A/(H5N1)) (WHO 2010).

The pledged figure of US$1.9 billion far exceeded the initial target, highlighting the perceived importance of this issue. Strengthening of disease surveillance and control systems in developing countries was a significant component of this fund. Another significant part of the fund was earmarked for controlling the spread of the disease, especially through the preservation of livelihoods so as to improve reporting of an outbreak by the poor. In the specific context of HPAI outbreaks (and outbreaks of other animal diseases), disease control and livelihoods preservation are inextricably linked. The incentive to report an outbreak, and thus facilitate the implementation of control measures, is a function of the effect of HPAI on livelihoods.

This link rationalizes the system of compensation for the loss of poultry from control measures (a supply shock in economic terms). Traditional policies, including focusing solely on the supply shock effects, have tended to ignore the more nuanced elements of the HPAI shock. In this paper, we emphasize that, in economic terms, it is extremely important to treat an HPAI outbreak as both a demand shock (that is, a reduction in demand due to consumer panic and an associated fall in the price/value of poultry and eggs) and a supply shock (that is, a reduction in poultry supply as a result of disease mortality, control measures such as culling, or both). Demand shock is generally nonlocalized; more importantly, it can occur even in the absence of an outbreak, since it is a perception-based consumer response. The demand shock is also often discrete, and evidence from several countries suggests that the impact of a demand shock far outweighs that of a supply shock.

Characterization of the shocks as supply-and-demand shocks, compounded with the fact that HPAI spread is essentially transboundary, provides us with the first set of rationale for looking at the set of four SSA countries as a group. The two study countries in East Africa, Ethiopia and Kenya, have not yet experienced any outbreaks; however, they share a physical border with each other and with Sudan, where several HPAI outbreaks have occurred, thereby implying informal trade effects. The two study countries in West Africa, Ghana and Nigeria, have both experienced outbreaks and are effectively neighbors from a disease spread standpoint, being on the same bird flyways. Although the science of the channels of spread (trade, flyways, or both) is still not definitive, both channels are considered important in the spread of the disease.

Regarding the first channel—the trade linkage between Kenya and Ethiopia—the current low levels of trade (most of which is informal or undocumented) are often taken as a basis for downplaying the interdependence in disease transmission. This reasoning, we argue, ignores a very important dynamic—the endogenous initiation or expansion of trade following an outbreak. If Ethiopia has an outbreak and Kenya does not, and if livelihoods in Ethiopia are affected significantly, trading of birds out of Ethiopia will be a rational response, at least in the short run. Similarly, if both Kenya and Ethiopia have an outbreak or are affected through a demand–link channel, arbitrage will materialize with the transfer of birds toward high-compensation areas through informal trading.

The study countries represent a spectrum regarding HPAI status and the importance of poultry in small-scale producers' livelihoods outcomes. In Nigeria, HPAI is considered endemic; Ghana has experienced three outbreaks; in Kenya and Ethiopia, where HPAI outbreaks have not yet occurred, scares and threats have significantly affected the poultry sectors. The countries also differ in various other factors, including the size and structure of the poultry sector, reliance of the poor on poultry, and the levels of diversification in income sources and in assets that determine the capacity to cope with shocks.

This paper contributes to the literature in different ways. An increasing number of studies have investigated the economywide, intersectoral, or sectorwide impacts of HPAI in several SSA countries (You and Diao 2007; Diao 2009; Diao, Alpuerto, and Nwafor 2009; Schmitz and Roy 2009; Thomas, Diao, and Roy 2009; Thurlow 2009). Some of these studies are linked with household data through microsimulation routines to assess the impact at the household level.

Important as these effects are, they do not assess effects at the household level or do so in a summary (for example, households clubbed into decile groups). Most importantly, these studies cannot differentiate across households based fully on their income and asset portfolio. The number of studies that investigate the impact of HPAI on small-scale, household-level producers' livelihoods is scarce (Bush 2006; Kimani, Obwayo, and Muthui 2006; UNDP 2006; Obayelu 2007; UNICEF/AED 2008). These studies are mainly based on both qualitative and quantitative data generated through rapid assessment techniques conducted as case studies in selected states or regions of the study countries, as mentioned above. We argue that both the area/region-specific case studies and qualitative methods have significant limitations when producing estimates of the impact of the shock on livelihoods. These location-specific case studies can present a very biased picture and do not generate policy prescriptions for resource allocation, which is a very important requirement in developing economies under strict budget constraints. The same critique applies to qualitative methods.

Starting from the assumption that poultry plays a considerable role in household-level producers' various livelihoods outcomes, such as cash income, wealth, food and nutrition security, intrahousehold gender equality, and insurance against shocks (Gueye, 1998, 2000, 2005; Kushi, Adegbola, and Umeh 1998; Kitalyi 1998; Tadelle and Ogle 2001; Tadelle et al. 2003; Njenga 2005; Aboe et al. 2006; Blackie 2006; Aklilu et al. 2008; Chinombo et al. 2001), we see merit in conducting a detailed investigation of the impact of HPAI on small-scale, household-level poultry producers' livelihoods by using rigorous quantitative methods. The evidence from all four study countries clearly shows that a great majority of the poultry populations of these countries are managed by household-level producers, with minimal or no biosecurity measures (Alemu et al. 2008; Aning, Turkson, and Asuming-Brempong 2008; Obi, Oparinde, and Maina 2008; Omiti and Okuthe 2008).

Therefore, information regarding the role of poultry in the livelihoods of small-scale poultry-producing households and the livelihoods impacts of HPAI-induced supply-and-demand shocks is critical for the design of targeted, effective control and mitigation policies. This paper aims to fill the gap in the literature by using nationally representative household-level data from the study countries to answer the following questions:

1. Who are the poultry keepers? Are they poor? Do they have diversified income or asset portfolios, or both? Within a country, where are they located? Are there significant regional differences?
2. Among the poultry keepers, what is the intensity of participation in poultry production? Who are the poultry keepers that participate in this sector with greater intensity, and where are they located? In quantitative terms, we examine these questions by assessing the flock sizes of the household-level poultry keepers.
3. What are the characteristics and locations of poultry producers in the study countries who are likely to bear the brunt of the disease? This can be hypothesized through Items 1 and 2 together.
4. What is the effect of the disease outbreaks and scares/threats on livelihoods outcomes? How can we assess this effect in the absence of actual data on affected households?

The results of our analyses highlight some interesting and important policy implications. Our reliance on nationally representative data provides an ex post vindication by revealing the significant interregional disparities in households' income and asset portfolios. As explained previously, most of the studies looking at the effect of these shocks are localized and case study-based (that is, based on one area or region of a study country) and therefore cannot be treated as generalizable. In addition, the datasets that we use in this study allow us to look at the whole income and asset portfolio rather than solely the poultry income, thereby providing a more accurate measure of the impact of the disease. If one looked only at the impact of HPAI on the income from poultry without accounting for its role in the whole income stream, the effects could be grossly inaccurate and even exaggerated.

Contrary to our ex ante conjecture, we were surprised to find that poultry-producing households are significantly diversified in the four study countries, though there are significant within-country regional differences. When livelihoods portfolios are diversified, any idiosyncratic shock would have only limited effect, particularly if the livelihoods activity that is affected by the shock has a small contribution to the overall income and asset portfolio. This idea turns out to be true in the case of poultry for most regions in the study countries, although the regional differences in impacts need attention. More importantly, our results highlight the significance of the nature of the shock. An idiosyncratic shock to a specific sector (such as the small-scale poultry sector) implies negligible covariance with other sectors (such as other livestock or crop production). In the short to medium run, however, the evidence from the SSA countries studied here shows that a shock to an important livestock activity undertaken by the poor will not have a significant livelihoods effect, on average. While this result is important, it does not imply that earmarking of funds for preserving livelihoods is not important in African countries. As long as poor are loss averse and effects on livelihoods are nonzero, there exists a significant potential for small effects on livelihoods to translate into first-order effects on disease control.

The remainder of the paper is organized as follows. Section 2 provides background information regarding the HPAI status in each study country and summarizes the documented evidence on poultry supply-and-demand shocks caused by HPAI outbreaks and scares in these countries. Section 3 explains the econometric models used to tackle the research questions. Section 4 introduces the data sources and presents descriptive statistics. Section 5 reports the results of the analysis, and Section 6 concludes the paper with implications for HPAI prevention and control policies.

2. BACKGROUND: HPAI STATUS AND ECONOMIC IMPACTS

In this paper we study two West African countries, Nigeria and Ghana, which have experienced multiple HPAI outbreaks. In Nigeria, there have been several HPAI outbreaks since February 2006, affecting 27 out of 36 states; the most recent outbreak occurred in July 2008 (Obi, Oparinde, and Maina 2008). According to the records of the World Bank-funded Avian Influenza Control Program, between February 2007 and January 2008, ₦623, 077,880 (US$4,215,683) was paid to compensate farmers whose birds were culled. No information is available on the costs of culling, diagnostic testing of samples, cleaning and disinfection, and other administrative costs (Obi, Oparinde, and Maina 2008).

Regarding the impacts of HPAI on the poultry sector, a study conducted by the United Nations Development Programme in 2006, immediately following the initial outbreaks, revealed that the official confirmation of HPAI in Nigeria caused initial panic resulting in the total boycott of poultry and poultry products. Consequently, within two weeks, egg and chicken sales declined by 80.5 percent due to demand shock; up to four months afterward, prices had not recovered up to 50 percent pre-HPAI levels. The study found that although the highest bird mortality rates occurred in commercial farms, the poultry incomes of small-scale, household-level producers, especially in rural areas, as well as medium-scale producers, were most severely affected by the HPAI outbreaks, since these smaller-scale producers lack necessary assets for recovery and often do not qualify for compensation (especially village-extensive, small-scale poultry-producing households). Affected backyard producers suffered up to a 100 percent poultry income loss, and nonaffected producers witnessed poultry income losses as high as 68.2 percent (UNDP 2006; Obi, Oparinde, and Maina 2008).

State-level studies conducted in Nigeria found that HPAI resulted in a 57 percent drop in chicken prices in the state of Kwara (Obayelu 2007). The household-level demand shock was as high as 80 percent; as a result of supply shock, 75 percent of poultry farmers stopped ordering new supplies of birds and opted out of poultry farming altogether. According to Obayelu (2007), small-scale commercial producers and backyard poultry farmers suffered the most poultry income losses as a result of HPAI. A more recent study conducted by the United Nations Children's Fund and the Academy for Educational Development in the states of Kano and Lagos found that HPAI shocks resulted in substantial losses in employment in the poultry sector, as well as sharp decreases in prices of poultry. In Kano, the price of chicken in the markets dropped by as much as 90 percent, and in Lagos the price fell by 81.25 percent (UNICEF/AED 2008).

Anecdotal evidence from Ghana suggests that during the 2006 outbreaks in the neighboring countries, the supply-and-demand shocks were large. With respect to supply shocks, poultry producers could not sell their produce; due to the increasing costs of keeping poultry (for example, feeding and maintaining costs), they had to dispose of their produce as quickly as possible and hence sold at extremely low prices. For example, a crate of eggs was sold at 63.3 percent of its normal price (Aning, Turkson, and Asuming-Brempong 2008). With respect to demand shocks, the Ministry of Food and Agriculture of Ghana reported that "the scare of the bird flu alone led to a drastic reduction in the demand for poultry and poultry products" (Aning, Turkson, and Asuming-Brempong 2008).

There were three actual outbreaks of HPAI in Ghana in 2007 (Aning, Turkson, and Asuming-Brempong 2008). No published information is available on the supply-and-demand shocks or changes in prices after the outbreaks. There is, however, anecdotal information on the number of farmers who have gone bankrupt due to the loss of markets as a result of the ban on poultry and the reductions in the demand for poultry products during and after the outbreaks. According to the Poultry Farmers' Association, the total number of its broiler-producing members fell significantly (from 62 to only 3), whereas the number of its egg-producing members also fell, though at a lower rate (from 47 to 33). At the country level, the total number of egg producers plummeted from 1,500 to 500. These figures provide some indicators of the supply-and-demand shocks suffered by poultry farmers in Ghana (Aning, Turkson, and Asuming-Brempong 2008).

In this paper we also study two East African countries, Kenya and Ethiopia, which have not had actual HPAI outbreaks to date. These two countries have, however, experienced HPAI scares or threats, which also affect the poultry sector and the household-level livelihoods outcomes through the demand shocks they cause. Both countries are highly susceptible to the introduction of HPAI. Kenya is located along a migratory route of wild birds, and both countries share a border with neighboring Sudan, where the virus is present and where illegal trade activities across the borders are paramount (Alemu et al. 2008; Omiti and Okuthe 2008). Given the susceptibility of these two countries to HPAI, we wanted to understand the ex ante livelihoods impact of a possible HPAI outbreak and the role of poultry in the households' livelihoods.

A major HPAI scare took place in Kenya from September 2005 through March 2006 (Omiti and Okuthe 2008). The scare was initiated by misguided reports by the media compounded by actual HPAI outbreaks in neighboring Sudan. Kimani, Obwayo, and Muthui (2006) assess the supply-and-demand shocks caused by this scare to be highly significant. According to their study, as a result of this scare, 25 percent of farmers prematurely culled their birds, and all farmers interviewed reduced their flock sizes between 2 and 39 percent due to various reasons related to the scare (premature selling, postponement or cancellation of day-old chicks, and unavailability of new chicks as hatcheries reduced production). The prices of poultry and poultry products were also affected by the HPAI scare. The price of broiler chickens fell by 15 percent per kilogram, and the price of eggs fell by 15.3 percent per crate. The supply-and-demand shocks caused by the scare also reduced the prices of indigenous eggs and chickens by 7.2 percent per crate and 26.5 percent per kilogram, respectively (Kimani, Obwayo, and Muthui 2006). The overall financial losses associated with the HPAI scare are estimated to be Ksh2.3 billion (US$30.7 million) (Omiti and Okuthe 2008).

In Ethiopia, there was an HPAI scare in 2006 due to a false alarm in a state-run poultry multiplication center. This scare caused a massive demand shock, which subsequently led to sharp falls in poultry prices (Alemu et al. 2008). Bush (2006) reports that this demand shock, which was especially strong in urban areas, resulted in a decrease in poultry demand by 25 to 30 percent. As a result of reduction in urban demand and the consequent oversupply of local markets, the prices of chickens sold at the local markets dropped by 50 to 60 percent. However, the scare did not affect egg supply, demand, or price (Bush 2006).

3. METHODOLOGY

As stated in the Introduction, in order to understand the impact of HPAI on livelihoods, we first profile the characteristics of the households that choose poultry production as a livelihoods activity; among these households, we profile the characteristics of those households that are engaged in more intensive poultry production. To investigate these issues, we estimate probit and zero-inflated count data models, respectively. We then measure the livelihoods impacts of the HPAI supply-and-demand shocks on households that are engaged in poultry production and intensive poultry production. For the latter analysis we use the propensity score matching approach. Information on the poultry-keeping and intensive-poultry-keeping households' profiles, as well as information on the livelihoods impacts these households may suffer, is expected to aid in the design of targeted interventions. The econometric models used in this paper are explained in greater detail below.

Determinants of Participation in Poultry Production

Household-level participation in poultry as a livelihoods activity is modeled following the random utility framework proposed by McFadden (1974). A nonseparable farm household model is assumed, given that a great majority of small-scale poultry producers in the study countries are noncommercial or semicommercial producers who mainly produce for their own household consumption (Singh, Squire and Strauss 1986; de Janvry, Fafchamps and Sadoulet 1991). A reduced form of the model for a poultry producer with missing markets for poultry products describes the overall welfare of the household to be a function of the household (H)- and farm (F)-level characteristics, as well as regional factors (R) such as market integration and density of poultry. That is,

$$U = U(\Omega_H, \Omega_F, \Omega_R) \quad (1)$$

Let $U_i^*(\Omega)$ denote the maximum utility level that household i can achieve given its constraints if the household participates in poultry production activity. Let $U_{-i}^*(\Omega)$ denote otherwise maximum constrained utility. Both utility levels assume optimal choices of production and consumption.

In the random utility model, the utility the household derives from undertaking poultry activity consists of two parts, an observable part and an unobservable part (McFadden 1974). The utility levels the household derives from participating in poultry production and otherwise are, respectively,

$$U_i^*(\Omega) = \overline{U}_i^*(\Omega) + \varepsilon_i$$

and

$$U_{-i}^*(\Omega) = \overline{U}_{-i}^*(\Omega) + \varepsilon_{-i} \quad (2)$$

The household chooses to participate in poultry production if, and only if, the utility the household derives from participating in the poultry activity is higher than that of not participating in it. That is,

$$\overline{U}_i^*(\Omega) + \varepsilon_i \succ \overline{U}_{-i}^*(\Omega) + \varepsilon_{-i}$$

or

$$\overline{U}_i^*(\Omega) - \overline{U}_{-i}^*(\Omega) \succ \varepsilon_{-i} - \varepsilon_i \quad (3)$$

The level of utility derived from poultry activity is not observable; however, the household's actual choice is. For the dichotomous choice case, the household's choice to participate in poultry production can be characterized by a variable I_i, such that

$$I_i = \begin{cases} 1 \text{ if } U_i^*(\Omega) \succ U_{-i}^*(\Omega). \\ 0 \text{ if } U_i^*(\Omega) \leq U_{-i}^*(\Omega). \end{cases} \tag{4}$$

The household makes a decision about whether or not to participate in poultry production. The solution to this participation decision yields the household's optimal participation choice I^*, where the probability of observing a household's participation in poultry activity is given by

$$\Pr(i) = \Pr(I_i^* = 1) = \Pr(U_i^*(\Omega) \succ U_{-i}^*(\Omega)) = M(\bar{U}_i^*(\Omega) - \bar{U}_{-i}^*(\Omega) \succ \varepsilon_{-i} - \varepsilon_i), \tag{5}$$

where it is commonly assumed that both error terms are normally distributed with mean zero and constant variance and where M is their cumulative distribution function that is assumed to have a standard normal distribution. In this study, therefore, whether or not a household decides to participate in poultry production implicates a dichotomous, binary choice. Equation 5 can be estimated with a univariate probit model for a binary outcome of taking part in this livelihoods activity.

Determinants of Poultry Flock Size

The Poisson model for count data is used to model the household's decision regarding the number of birds to keep (Greene 1997a). The probability of raising k number of poultry given n independent possibilities is represented by the binomial distribution

$$P(Y = k) = \binom{n}{k} p^k (1-p)^{n-k}, \tag{6}$$

where $\binom{n}{k} = \frac{n!}{k!(n-k)!}$ and p is the probability of keeping k number of poultry.

Statistical theory states that a repetition of a series of binomial choices, from the random utility formulation, asymptotically converges to a Poisson distribution as n becomes large and p becomes small.

$$\lim_{n \to \infty} \binom{n}{k} p^k (1-p)^{n-k} = \frac{e^{-\lambda} \mu^k}{k!}, \tag{7}$$

where $p = \mu / n$ and μ is the mean of distribution, such as the mean number of poultry kept per household. This formulation allows modeling of the probability that a household chooses to raise a number of poultry (k) given a parameter μ (the sample mean). Each household makes a series of discrete choice decisions about whether or not to raise poultry on the farm, resulting in the number of poultry kept. Accordingly, Poisson specification is used to model the increase in household utility from an additional bird raised. The Poisson regression model is the development of the Poisson distribution presented in Equation 7 to a nonlinear regression model of the effect of independent variables x_i on a scalar dependent variable y_i. The density function for the Poisson regression is

$$f(y_i / x_i) = \frac{e^{-\mu_i} \mu_i^{y_i}}{y_i!}, \tag{8}$$

where the mean parameter is the function of the regressors x and a parameter vector β is given by

$$E(y_i / x_i) = \mu_i = \exp(x_i^{'}\beta) \qquad and \qquad y = 0,\ 1,\ 2,\ ... \tag{9}$$

where

$$\exp(x_i^{'}\beta) = \exp(\beta_0) + \exp(\beta_1 x_{1i}) + \exp(\beta_2 x_{2i}) \ \ ... \ \ + \exp(\beta_k x_{ki}) . \tag{10}$$

Also note that

$$\beta_j = \frac{\partial E[y_i / x_i] / \partial x_{ji}}{E[y_i / x_i]} = \frac{\partial \log E[y_i / x_i]}{\partial x_{ji}} . \tag{11}$$

That is, the coefficients of the marginal effects of the Poisson model can be interpreted as the proportionate change in the conditional mean if the *j*th regressor changes by one unit.

Finally, the Poisson model sets the variance to equal the mean. That is,

$$V(y_i / x_i) = \mu_i(x_i, \beta) = \exp(x_i^{'}\beta) . \tag{12}$$

This restriction of the equality of the mean and variance in the Poisson distribution is often not realistic, as it has been found that the conditional variance tends to exceed the mean, resulting in an overdispersion problem (Cameron and Trivedi 1986; Grogger and Carson 1991; Winkelmann 2000). If an overdispersion problem exists, the conditional mean estimated with a Poisson model is still consistent, though the standard errors of β are biased downward (Grogger and Carson 1991). A more generalized model to account for the overdispersion problem is based on the negative binomial probability distribution expressed as

$$f(y_i / \mu, \alpha) = \frac{\Gamma(y + \alpha^{-1})}{\Gamma(y+1)\Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu} \right)^{\alpha^{-1}} \left(\frac{\mu}{\alpha^{-1} + \mu} \right)^{y} , \tag{13}$$

where

$$\mu_i = \exp(x_i^{'}\beta) \qquad y = 0,\ 1,\ 2,\ \ldots \tag{14}$$

and $\alpha \geq 0$ characterizes the degree of overdispersion, or the degree to which the variance differs from the mean.

Cameron and Trivedi (1990) have proposed a regression-based test for overdispersion, which tests for the significance of the α parameter as compared with the Poisson model (Greene 1997b). The test is based on the hypothesis that the Poisson model $(y - E[y])^2 - E[y]$ has mean zero and that under both the null and the alternative hypotheses, the Poisson model gives consistent estimates of $E[y_i] = \mu_i$. The test is based on the hypotheses

$$H_0 : Var[y_i] = \mu_i , \tag{15}$$

versus

$$H_1 : Var[y_i] = \mu_i + \alpha g(\mu_i) .$$

In this study, the test of equality of the mean and variance fails to hold for any of the study countries. Therefore, the negative binomial model is considered. However, in each study country there are many zero observations for households that did not keep poultry in the survey year in which the data were collected. Consequently, the zero-inflated negative binomial (ZINB) model was estimated to account for both the overdispersion and the excess zeros (Long 1997; Greene 1997b).

In the ZINB model, for each observation, there are two possible data generation processes; the result of a Bernoulli trial determines which process is used. For observation i, Process 1 is chosen with probability φ_i and Process 2 with probability $1 - \varphi_i$. Process 1 generates only zero counts, whereas Process 2, $g(y_i|\mathbf{x}_i)$ generates counts from a negative binomial model:

$$y_i \sim \begin{cases} 0 & \text{with probability } \varphi_i \\ g(y_i|\mathbf{x}_i) & \text{with probability } 1 - \varphi_i \end{cases}. \tag{16}$$

The probability of $\{Y_i = y_i|\mathbf{x}_i\}$ is

$$P(Y_i = y_i|\mathbf{x}_i, \mathbf{z}_i) = \begin{cases} \varphi(\gamma'\mathbf{z}_i) + \{1 - \varphi(\gamma'\mathbf{z}_i)\}g(0|\mathbf{x}_i) & \text{if } y_i = 0 \\ \{1 - \varphi(\gamma'\mathbf{z}_i)\}g(y_i|\mathbf{x}_i) & \text{if } y_i > 0 \end{cases}. \tag{17}$$

When the probability φ_i depends on the characteristics of observation i, φ_i is written as a function of $\mathbf{z}_i{'}\gamma$, where $\mathbf{z}_i$ is the vector of zero-inflated covariates and γ is the vector of zero-inflated coefficients to be estimated. The function F that relates the product $\mathbf{z}_i{'}\gamma$ (which is a scalar) to the probability $\varphi_i$is called the *zero-inflated link function,* and it can be specified as either the logistic function or the standard normal cumulative distribution function (the probit function) (Greene 1997b).

The mean and variance of the ZINB are

$$\begin{aligned} E(y_i|\mathbf{x}_i, \mathbf{z}_i) &= \mu_i(1 - \varphi_i) \\ V(y_i|\mathbf{x}_i, \mathbf{z}_i) &= \mu_i(1 - \varphi_i)(1 + \mu_i(\varphi_i + \alpha)), \end{aligned} \tag{18}$$

To test whether the ZINB model fits to the data better than the negative binomial model for each study country, we performed the Vuong test. This test is for nested models and is used to determine which zero-inflated model explains the data better (Vuong 1989). The test favors the ZINB model for all countries, suggesting that there is a separate process for households' decisions to keep poultry and decisions regarding the number of poultry to keep.

Finally, in this study we calculate Theil's inequality coefficient, which is also known as Theil's U, in order to determine how well the estimated results of the ZINB model explain the actual data (Jang 2005). This coefficient is a statistic related to the root mean square forecast error:

$$U = \frac{\sqrt{\frac{1}{n}\sum_i (X_i - Y_i)^2}}{\sqrt{\frac{1}{n}\sum_i X_i^2} + \sqrt{\frac{1}{n}\sum_i Y_i^2}}, \tag{19}$$

where n is the number of observations, X_i is the forecast value, and Y_i is the actual value. The closer the value of U is to zero, the better the model fit.

Estimating Livelihoods Impact of HPAI Using the Propensity Score Matching Method

Since we do not have nationally representative data on the same households from before and after the HPAI outbreaks or scares/threats, we use an ex ante evaluation method as proposed by Ichimura and Taber (2000) and Todd and Wolpin (2006). The main feature of this approach is based on the fact that all the factual outcomes are about nontreated individuals; that is, none of them has yet been exposed to the policy (in this case, HPAI outbreak or shock) that the analyst is to evaluate. The matching procedure is between an individual *i* about whom we observe (or estimate) the outcome as nontreated and an individual *j* who mimics the outcome individual *i* would have under the treatment (that is, an HPAI shock). Then it must be $Y_i^1 = Y_j^0$; that is, the factual outcome for individual *j* under the status quo policy regime must be equal to the one of individual *i* under the HPAI shock (hereafter referred to as *the treatment*).

The estimation of an average treatment effect in observational studies can produce biased results when we use a nonexperimental estimator. The typical problem in this type of study is that the assignment of subjects to the treatment and control groups is not random; therefore the estimation of the average treatment effect is usually biased as a result of the existence of confounding factors. For that reason, the matching between treated and control subjects becomes difficult when there is an *n*-dimensional vector of characteristics. The matching approach is one possible solution to the selection problem and has become a popular approach to estimating causal treatment effects (Caliendo and Kopeinig 2008). Its basic idea is to find a large group of nontreated individuals or households that are similar to the participants in all relevant pretreatment characteristics *X*. That being done, differences in outcomes of this well-selected and thus adequate control group and of the treated group can be attributed to the treatment.

Because conditioning on all relevant covariates is limited in the case of a high-dimensional vector *X* ("curse of dimensionality"), Rosenbaum and Rubin (1983) suggest the use of so-called balancing scores *b*(*X*), functions of the relevant observed covariants *X* such that the conditional distribution of *X* given *b*(*X*) is independent of assignment into treatment. This is the conditional independence assumption (CIA). One possible balancing score is the propensity score, the probability of participating in a treatment given observed characteristics *X*. The matching procedures based on this balancing score are known as propensity score matching (PSM).

Besides CIA, a second assumption of matching requires that treatment observations have comparison observations "nearby" in the propensity score distribution. This common support or overlap condition ensures that persons with the same *X* values have a positive probability of being both participants and nonparticipants (Heckman, LaLonde, and Smith 1999). The common support thus represents the area where there are enough of both control and treatment observations. The common support region allows effective comparisons of outcomes between the treated and control groups.

Assuming the CIA holds and that there is overlap between both groups, the average treatment effect can then be estimated. One ideally wants to estimate $\Delta = Y_t^1 - Y_t^0$, which is the difference of the outcome variable of interest at time *t* between two groups, denoted by the superscripts 1 and 0. However, the econometrician is unable to estimate Δ in this way because a household cannot simultaneously be in the treatment and the control groups. The econometrician is thus forced to measure the average treatment effect (ATE) given the observable data:

$$ATE = E(Y_t^1 | T = 1) - E(Y_t^0 | T = 0) \quad (20)$$

When data are generated through a properly implemented random experimental design, the expectations of the treatment and comparison groups are equal because the groups are composed of randomly allocated members (households), ensuring that the distribution of observable and unobservable characteristics of the groups are equivalent in a statistical sense. With a randomized design, the selection bias equals zero, which establishes that the estimate of the ATE provides an unbiased estimate of its impact.

Randomized experiments are not always possible (for example, in the case of estimation of the impacts of HPAI on livelihoods) or plausibly implemented, so absence of selection bias is a credible assumption. Hence, econometricians are often forced to estimate the average treatment effect on the treated households (ATT), given a vector household characteristic, *X:*

$$ATT = E(\Delta | X, T = 1) - E(Y_t^1 - Y_t^0 | X, T = 1) = E(Y_t^1 | X, T = 1) - E(Y_t^0 | X, T = 0) \quad (21)$$

To estimate potential effects of HPAI incidence, propensity scores are used to match households with similar observable characteristics, varying only in the treatment, which in this case is having poultry (and therefore being susceptible to HPAI). Households are matched based on a set of observable household characteristics. A probit model is estimated using a vector of household characteristics to obtain predictions of household propensity scores. Heckman, Ichimura, and Todd (1998) observe that the PSM has lower bias when *X* includes variables that affect both program participation and outcome. The household-level characteristics (household demographics, assets, poverty status, number of income sources, and regional characteristics such as location) included in the model are therefore those that have a high probability of influencing participation in poultry production, as well as outcome variables, including livelihoods indicators such as livestock income and wealth. According to this method of matching, the two groups—which include the treatment group of households representing the result of the HPAI-induced supply-and-demand shocks and the control group representing the status quo (if no HPAI shocks occurred)—should differ only in their poultry ownership characteristics.

In this study we simulate six counterfactual scenarios to estimate the possible impact of HPAI on livelihoods indicators (income and asset wealth) for poultry-producing households. These scenarios consider the livelihoods impacts of both demand (Scenario 4) and supply shocks (all other scenarios), as well as the impact of the supply shocks on poultry keepers of different scales. The duration of the livelihoods impacts of these shocks are assumed to be one year. This is because the variables used to derive the impacts of these shocks (which include whether or not the household had poultry in the last 12 months, number of poultry owned in the last 12 months, and household total income/expenditure in the last 12 months) are all annual data collected through the nationally representative survey instruments.

It is likely that the impacts of the shocks could be shorter or longer than the one year assumed in this study. In the case of a supply shock (such as culling), farmers are generally allowed to restock within about three months after culling (exact timing depends on the country). Farmers who could afford to and who are still interested in being a poultry producer could restock as soon as they are allowed, whereas some could take longer to restock, if they do at all, depending on the impact of the shock on the household livelihoods outcomes and assets. In addition, it is expected that the duration of the recovery from shock would depend on the initial flock size and impact of the supply shock thereon. For example, producers who lose larger flocks could take longer to recover from such shocks, whereas those with fewer birds (one or two) could recover in a shorter time period. The duration of the shocks would also depend on the existence and magnitude of the compensation provided to those whose birds are culled.

Similarly, the impact of the demand shock could be shorter than one year. In Section 2, it is stated that in the case of Nigeria, for example, poultry prices had not recovered to their pre-shock levels four months after the outbreak. However, rigorous studies on the duration of HPAI-induced supply-and-demand shocks (that is, how long it takes households to recover their livelihoods outcomes to their pre-HPAI shock levels) are missing. Therefore, we assume the duration of the shocks to be one year, as it is consistent with the data at hand.

In order to estimate the impact of HPAI on small-scale poultry producers, in this study we divide producers into two groups across study countries, with "smaller" small-scale producers representing those poultry producers with 1 bird to the 25th percentile number of birds and more intensive "larger" small-scale producers having more than the 25th percentile number of birds but fewer than 500 birds, where 500 is the cutoff point for small-scale household-level poultry keeping in the study countries (Alemu et al. 2008; Aning, Turkson, and Asuming-Brempong 2008; Omiti and Okuthe 2008; Obi, Oparinde, and Maina 2008). Across scenarios, Scenario 2 considers the impact of HPAI on “smaller” small-scale producers, whereas Scenarios 3 and 6 consider the impact of HPAI on “larger” small-scale producers. Moreover, integration of our impact assessment with the diseases risk maps developed by Stevens et al. (2009) enables us to measure the livelihoods impacts in different risk areas (Scenarios 5 and 6).

Scenario 1 assumes a countrywide shock where all poultry-producing households in the study country experience a total loss (that is, a 100 percent loss) of their poultry flock due to HPAI. In this scenario, outcomes of households with poultry are compared with those without poultry. Scenario 2 investigates the impact of HPAI on "smaller" small-scale poultry producers. The assumption is that only those households with "smaller" small-scale flocks are affected by HPAI, losing all (100 percent) of their flocks. Scenario 3 assumes that only "larger" small-scale producers are adversely affected by HPAI, losing some of their birds and being left with a flock size similar to that of the "smaller" small-scale producers.

Scenario 4 assesses the impact of a demand (price) shock caused by HPAI. We assume this shock to be countrywide. We look at the impact of a price shock on the livelihoods outcomes of those chicken producers who sell poultry. Of those households that sell chicken, we compare households that get higher prices (above the median chicken price in each country) with those that get lower (below-median) prices.

Scenarios 5 and 6 use the disease spread map developed by Stevens et al. (2009), which shows the likelihood for the spread of HPAI in each study country, assuming that the disease has been introduced for those countries where there is currently no HPAI. In Scenario 5, households located in areas with high HPAI spread risk are assumed to be affected by HPAI and to lose 100 percent of their birds. As in Scenario 1, poultry-producing households are compared to those with no poultry; however, in this scenario, only those households in the high-risk areas are matched. Finally, in Scenario 6, we use the disease spread risk map to identify mid-level risk areas in each study country (Stevens et al. 2009). As in Scenario 3, this scenario assumes that only "larger" small-scale producers are adversely affected by HPAI and that they lose some of their birds and are left with a flock size similar to that of the "smaller" small-scale producers; however, in this scenario, only those households in the mid-level risk areas are matched. These scenarios are summarized in Table 1.

Table 1. Description of HPAI scenarios for poultry keeping at the household level

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5***	**Scenario 6***
Description of simulated impact	100% loss of poultry flock	100% loss of small-scale poultry flock	75–85% loss in large-scale poultry flock	50% reduction in poultry price	100% loss of poultry flock in high-risk areas	75–85% loss in large-scale poultry flock in mid-level risk areas
Treatment group	All households without poultry	All households without poultry	Small-scale poultry keepers (1 to *x* birds)	Poultry keepers who sold at low prices	All households without poultry	Small-scale poultry keepers (1 to *x* birds)
Control group	All households with poultry	Small-scale poultry keepers (1 to *x*[†] birds)	Large-scale poultry keepers (*x* to 500 birds)	Poultry keepers who sold at high prices	All households with poultry	Large-scale poultry keepers (*x* to 500 birds)

Source: Authors.

Notes: *For Scenarios 5 and 6, country-level disease spread maps (Stevens et al. 2009) were used to allocate locations (districts, provinces, or zones) into high HPAI spread risk and mid-level HPAI spread risk areas.

[†] The 25th percentile number of birds in each study country.

4. DATA SOURCES AND DESCRIPTIVE STATISTICS

Data Sources

This study relies on the latest nationally representative data from each study country. There are two advantages to using nationally representative data to study the role of poultry in households' livelihoods and the impact of HPAI. First, having nationally representative data enables us to investigate the regional or location-related variations, such as urban versus rural areas or high HPAI risk versus low HPAI risk regions, which targeted case studies may not allow. Second, the datasets used in this study are from studies whose aim is to monitor the changes in the welfare (poverty) levels in the study countries through time. Consequently, these studies have collected detailed data on the households' various sources of income and livelihoods strategies, as well as on the type and quantity of assets owned by the households. Therefore, these datasets allow us to investigate in detail the role of poultry (both as a source of income and as an asset) in the entirety of the households' income and asset portfolios.

Regarding the sources of data used in this study, for the West African countries we used the Living Standards Measurement Study (LSMS) survey data. For Nigeria we used the Nigerian Living Standard Survey 2004–2005 (NLSS 2004–2005), which was collected by the National Bureau of Statistics, the World Bank, and the National Planning Commission. For Ghana we used the Ghana Living Standards Survey 2005–2006 (GLSS 2005–2006), which was conducted by the Ghana Statistical Service with financial assistance from the World Bank. The data used for Kenya comes from the Kenya Integrated Household Budget Survey 2005–2006 (KIHBS 2005–2006), implemented by the Kenya National Bureau of Statistics and the Human Resources Social Services Department of the then Ministry of Finance and Planning. Finally, for Ethiopia we used the data from the Household Income and Consumption (HICE) survey conducted in 2004–2005, collected by the Ethiopian Central Statistical Authority. Each one of these studies collected data on the number of poultry kept by the sampled households in the study year and, in the case of Kenya, Nigeria, and Ghana, on the number of poultry sold and the price at which the poultry sold. For Ethiopia, we relied on monthly producer price data collected in 2004–05 by the Central Statistical Authority to derive the value of poultry owned by the households.

Descriptive Statistics

Descriptive statistics on participation in poultry production are reported in Table 2. According to the nationally representative data, 30 percent of all Nigerian households engage in small-scale poultry production, whereas this figure is 35 percent for Ghanaian households and 42 percent and 43 percent for Ethiopian and Kenyan households, respectively. In Ghana, Nigeria, and Kenya, greater proportions of rural households keep poultry, whereas in Ethiopia, poultry keeping is a popular activity among both urban and rural households. Across the study countries, poultry-producing households in Nigeria keep the largest flocks, with almost 17 birds, while the smallest flocks are kept by Kenyan poultry-producing households, with 2 birds. In Ghana, rural poultry-keeping households are found to keep statistically larger flocks compared with their urban counterparts, whereas no statistically significant differences between urban and rural areas were observed in other countries.

Table 2. Percentage of poultry-producing households, average flock size, and percentage of poultry income in total income

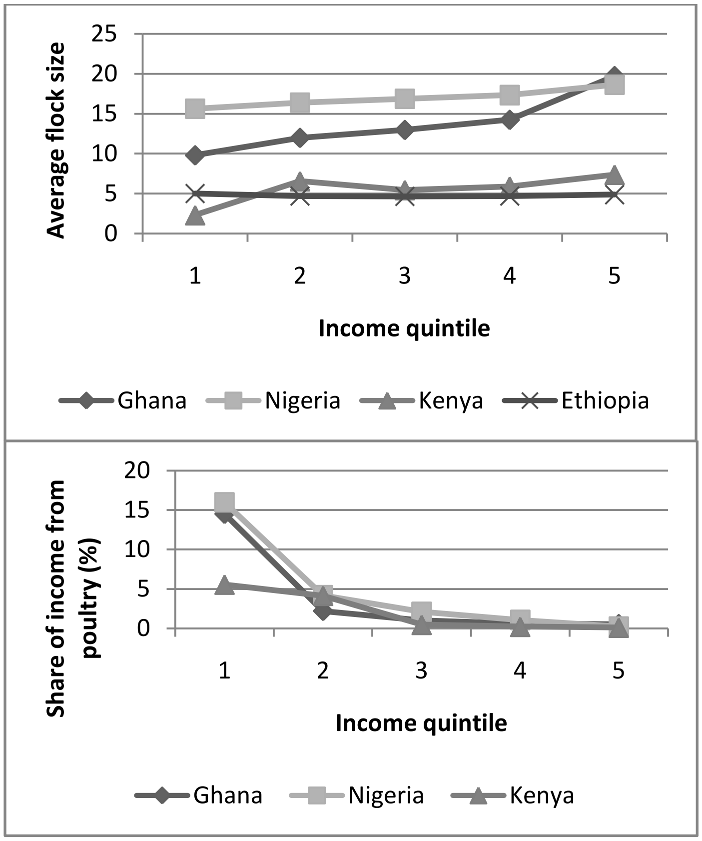
	All Households	Rural Households	Urban Households
ETHIOPIA			
% households that keep poultry	41.94	41.40	43.42
Average flock size of poultry keepers	4.82	4.81	4.83
	(7.43)	(8.08)	(5.35)
KENYA			
% households that keep poultry***	43	54	15
Average flock size of poultry keepers	14.57	14.30	16.38
	(25.76)	(23.79)	(36.56)
% poultry income in total income for poultry keepers	2.22	2.29	1.75
	(11.06)	(11.07)	(10.97)
GHANA			
% households that keep poultry*	34.6	51.43	11.03
Average flock size of poultry keepers***	13.74	13.77	13.54
	(15.48)	(14.31)	(21.70)
% poultry income in total income for poultry keepers	4.16	4.40	2.00
	(9.67)	(9.99)	(5.38)
NIGERIA			
% households that keep poultry*	29.70	37.20	6.33
Average flock size of poultry keepers	16.94	16.92	17.26
	(25.44)	(25.06)	(31.55)
% poultry income in total income for poultry keepers	5.61	5.63	5.08
	(17.23)	(17.26)	(16.72)

Source: Authors' calculations from HICE(2004-2005), KIHBS(2005-2006), GLSS(2005-2006) and NLSS(2004-2005).
Note: *Significantly different between urban and rural households * at 10%, and *** at 1% significance levels.

In this study, total annual household income includes salaries from employment (in agriculture, mining, manufacturing, services, and so on), income from livestock and crop sales, and remittances, rent income, and other reported income. On average, poultry (live bird) and egg sales contribute 4.1 percent to the poultry-producing households' total annual household income in Ghana, whereas this figure is as low as 2.1 percent in Kenya and as high as 5.61 percent in Nigeria. Across these three countries, the differences in the share of income from poultry between rural and urban poultry-keeping households were not statistically significant. In Ethiopia, HICE data did not include information on the number of live birds and eggs sold by the households; therefore, we could not calculate the share of income from poultry in total income for this country.

For poultry-producing households, the share of poultry income in total income and the number of birds kept across income quintiles are reported in Figure 1. The figures for Nigeria, Kenya, and Ghana reveal an overall increasing trend for flock size and a decreasing trend for the share of income obtained from poultry across income quintiles; that is, poorer households rely more on poultry to provide some of their income but have fewer birds compared with their wealthier counterparts. In Ethiopia, however, the average flock size is similar across income quintiles; since we do not have information on the number of live birds and eggs sold by the households, we cannot calculate the share of income from poultry for this country.

Figure 1. Average flock size and share of income from poultry, by income quintile



Source: Authors' calculations from HICE(2004–2005), KIHBS(2005–2006), GLSS(2005–2006), and NLSS(2004–2005).

5. RESULTS

Role of Poultry in Household Livelihoods

Estimating the Determinants of Participation in Poultry Production

As explained in Section 3, in order to understand the impact of HPAI on livelihoods, we must first profile those households that may choose poultry production as a livelihoods activity. Specifically, we are interested in finding out who the poultry keepers in each study country are—in other words, their social, economic, and location characteristics. Consequently, household-level social, economic, and agricultural factors, as well as regional factors that are hypothesized to affect households' decisions regarding whether or not to partake in poultry production, are investigated with a probit model.

Probit models are estimated for each country. The results of these models are reported in Table A.1 in the Appendix. For details of the country-level models, see the country reports (Ayele et al. 2010; Mensa-Bonsu et al. 2010; Ndirangu et al. 2010; Okpukpara et al. 2010). Each one of these models is highly significant according to the likelihood ratio test, and they perform well by assigning 67 percent (Ethiopia), 72 percent (Ghana), 75 percent (Kenya), and 85 percent (Nigeria) of predictions into the correct category. These models are used to predict each household's likelihood of being a poultry keeper. Those households with above 50 percent probability of being a poultry keeper are considered as predicted poultry keepers, and those with below 50 percent probability of being a poultry keeper are considered to be predicted nonkeepers of poultry. Household, farm, and location characteristics of predicted poultry keeper households are compared with those of predicted nonkeepers. The results of these comparisons are summarized in Table 3.

When compared with the predicted nonkeepers of poultry, households that are predicted to be poultry keepers are significantly larger. This finding is as expected because as the number of people in a household increases, both the household food and nutrition security needs and the household labor availability increase. In all countries, households with a higher proportion of adult women and children are more likely to be engaged in poultry keeping. This result is also as expected because previous studies (Aklilu et al. 2007; Sonaiya 2007) have shown that women and children tend to be involved in the rearing and selling of poultry. Children, especially in rural areas, often own one or two birds to meet their school materials costs (Hailemariam et al. 2006), whereas women are widely recognized to be the most important stakeholders in village-level poultry keeping in Africa, owning more than 70 percent of all household-level poultry (Alders 1996; Gueye 1998, 2000). In all of the study countries, households with less-educated heads are significantly more likely to keep poultry. The former result can be explained by the fact that in the study countries, household-level poultry production is a low-input, low-output activity that does not require high levels of skill and education (Alemu et al. 2008; Aning, Turkson, and Asuming-Brempong 2008; Omiti and Okuthe 2008; Obi, Oparinde, and Maina 2008).

Table 3. Characteristics of households predicted to be poultry keepers

Household, Farm, and Regional Characteristics	Ethiopia	Kenya	Ghana	Nigeria
Larger households	✓	✓	✓	✓
More adult women in the household	✓	✓	✓	✓
More children in the household	✓	✓	✓	✓
Less-educated household heads	✓	✓	✓	✓
More income sources	✓	✓	✓	✓
Other livestock production (small)	✓	✓	✓	✓
Other livestock production (large)	✓	✓	✓	✓
Crop production	✓	✓	✓	✓

Table 3. Continued

Household, Farm, and Regional Characteristics	Ethiopia	Kenya	Ghana	Nigeria
Less off-farm employment/income	✓	✓	✓	✓
Lower income per capita	✓	✓	✓	✓
Income below extreme poverty line	NS*	✓	NS	X
Higher livestock wealth	✓	✓	NS	✓
Higher overall wealth (house, land, livestock)	NA*	✓	NS	✓
Rural location	✓	✓	✓	✓

Source: Summary results of authors' estimations from HICE(2004-2005), KIHBS(2005-2006), GLSS(2005-2006), and NLSS(2004-2005).
Note: NS = not significant; NA = not applicable.

It is found that in all countries, households with more diversified livelihoods portfolios—that is, households with a higher number of income sources—are significantly more likely to be poultry keepers. Because poultry contributes a very small proportion to household income, as discussed in Section 4, this result is as expected. Related to this livelihoods diversification argument is the finding that across the study countries, those households engaged in other agricultural livelihoods strategies (other livestock, crop production, or both) and consequently those living in rural areas are significantly more likely to keep poultry. Previous studies have found that poultry production is often complementary with crop production, since farm manure and cropland area are inputs to poultry production by providing feed and area for scavenging and roaming. In fact, previous studies have found that households that own higher numbers of plot, larger areas, or both are more likely to keep livestock (for example, Wadsworth 1991). Moreover, households that own other livestock are also more likely to be engaged in poultry production, since poultry is often considered to be the first step in the livestock ownership ladder (for example, Gueye 2000; Aklilu et al. 2008). Therefore, overall, households that are predicted to be poultry keepers have diversified income sources and agricultural livelihoods strategies; consequently, their livelihoods outcomes are more likely to be resilient against shocks and stresses that may be caused by HPAI outbreaks and scares (Ellis 2000; Iiyama 2006).

In all of the study countries, predicted poultry keepers are found to have a lower number of household members with nonagricultural income, lower off-farm incomes, or both. Combined with the results discussed in the paragraph above, these results reveal that it is the rural, more agricultural, subsistence-oriented, or semisubsistence-oriented farm households with limited access to off-farm income opportunities who are engaged in poultry keeping. Related to these results is the finding that households that have lower income per capita are more likely to be poultry keepers. This finding is also expected, since household-level poultry keeping is often considered to be a livelihoods activity favored by the poor due to its high return rate compared with its low-input-investment requirements, as mentioned previously.

The impact of income below the poverty line on a household's likelihood of being a poultry keeper, however, is mixed across countries. In Kenya, households that are below the poverty line are more likely to keep poultry, whereas the opposite holds for Nigeria. For Kenya this result is consistent with the finding that larger households with higher adult female ratios are more likely to have incomes below the poverty line and to engage in poultry keeping (KPIA 2009). In Nigeria, where the average flocks of poultry-keeping households are the largest across study countries (Table 2), the finding may be explained by the fact that, in order to participate in poultry production, some minimum level of financial investment is needed. This investment may not be affordable for households whose incomes are below the poverty line.

Finally, we see that in all countries except Ghana, households that have higher livestock wealth (market value of livestock owned) are more likely to keep poultry. This result is as expected, since households that have other livestock are more likely to own poultry (as poultry is the first step in the livestock ladder, as mentioned previously). Kenyan and Nigerian households that are wealthier in terms of other assets (for example, house and land) are also more likely to keep poultry, possibly due to the complementarities between poultry production and crop production, as explained previously.

To identify the regional variations within the study countries, we use the probit model to calculate the percentage of households that are predicted to keep poultry in rural and urban areas, as well as in the different regions/districts of the countries. According to the probit model for Nigeria, 23 percent of all Nigerian households, 32 percent of rural households, and only 4 percent of urban households are predicted to be poultry keepers. Across geopolitical zones, a greater majority of households located in the northern zones (45 percent in the North West, 36 percent in the North East, and 28 percent in the North Central zones) are predicted to rear poultry. Among the southern zones, the South East is the zone with the highest proportion of predicted poultry keepers, with about 29 percent. According to the HPAI risk spread map developed by Stevens et al. (2009), the high HPAI risk areas in Nigeria mainly cover the South East zone, while the North Central, North East, and North West zones are mid-level HPAI risk areas.

According to the Ghana probit model, one-fifth of all Ghanaian households and 37 percent of rural households are predicted to be poultry keepers, whereas only 4.9 percent of urban households are predicted to keep poultry. Greater proportions of households located in the Upper East (80 percent), Upper West (56 percent), Northern (55 percent), and Volta (42 percent) regions are predicted to be household-level poultry keepers compared with households located in other regions. These four regions all fall under the high HPAI risk areas identified by Stevens et al. (2009).

In Kenya the probit model predicted 34 percent of all Kenyan households to be poultry keepers. In terms of their urban versus rural location, 53 percent of all rural households are predicted to keep poultry, whereas this figure is as low as 3 percent for urban households. Across provinces, 25 percent of all households in the Eastern Province are predicted to keep poultry, followed by Nyanza (22 percent), Western (19 percent), and Rift Valley (17 percent) provinces. According to the Stevens et al. (2009) disease spread risk map for Kenya, the high HPAI risk areas include districts in Western and Nyanza provinces, whereas Coast and Rift Valley provinces are designated as mid-level HPAI risk areas.

Finally, the probit model for Ethiopia predicted as high as 60 percent of all Ethiopian households to keep poultry. This figure is 66 percent in rural areas and 53 percent in urban areas, revealing that poultry keeping is a popular livelihoods activity in both urban and rural locations. Across regions, Tigray supports the highest proportion of households predicted to keep poultry, with 87 percent. Tigray is followed by Afar (86 percent), Benishangul Gumuz (71 percent), and Somale (65 percent). According to the Stevens et al. (2009) disease spread risk map for Ethiopia, the high HPAI risk areas include Benishangul Gumuz and Tigray, whereas Somale is designated as a mid-level HPAI risk area and Afar as a low HPAI risk area. Overall, in each one of the study countries, greater proportions of households located in riskier areas are likely to be poultry keepers, and, except for Ethiopia, a greater majority of rural households are likely to keep poultry.

Estimating the Determinants of Poultry Flock Size

This subsection profiles poultry keepers who keep larger flocks, since it is expected that those households engaged in more intensive poultry production would be more likely to suffer significant livelihoods impacts as a result of HPAI shocks. As explained in Section 3, following the results of overdispersion, Vuong, and likelihood ratio tests, the ZINB model is found to be the most appropriate model to describe the determinants of the size of flock managed by the households. In the logit component of the ZINB model (inflate panel), only the significant explanatory variables in the estimated probit models are used to determine the households' likelihood of being a "certain zero"—that is, of not keeping poultry. In the second component of the ZINB model, for those households that are not certain zeros, the household-, farm-, and regional-level factors that affect the size of the poultry flock they manage are estimated. The second part of the ZINB model for the study countries is presented in the Appendix in Table A.2. For details of the country-level models, see the country reports (Ayele et al. 2010; Mensa-Bonsu et al. 2010; Ndirangu et al. 2010; Okpukpara et al. 2010).

The probabilistic ZINB model is used to predict the flock sizes for each household that is predicted to participate in poultry keeping (that is, not certain zero). The predicted and actual flock sizes are reported in Table 4. According to the Theil inequality coefficients, which are all closer to zero, each of the models explains the actual data well.

Table 4. Actual and predicted average flock sizes and Theil's U, for all households in each study country

Study Country	Actual Average Flock Size Mean (Standard Deviation)	Predicted Average Flock Size Mean (Standard Deviation)	Theil's U
Ethiopia	2.22 (5.87)	2.23 (2.05)	0.29
Kenya	5.77 (17.70)	5.72 (5.04)	0.212
Ghana	11.54 (15.05)	10.71 (2.7)	0.12
Nigeria	5.03 (15.88)	4.95 (6.42)	0.14

Source: Authors' estimations from HICE(2004-2005), KIHBS(2005-2006), GLSS(2005-2006) and NLSS(2004-2005).

According to these predictions, an average predicted poultry-keeper household in Nigeria is predicted to keep 5 birds in 1 year, whereas this figure is 6 birds in Kenya, as low as 2 birds in Ethiopia, and as high as 11 birds in Ghana. In each country, households predicted to keep at least the mean number of birds are compared with households that are predicted to keep flocks with sizes below the predicted mean number of birds. The results of these comparisons are summarized in Table 5.

Table 5. Characteristics of households predicted to keep above-average-sized flocks

Household, Farm, and Regional Characteristics	Ethiopia	Kenya	Ghana	Nigeria
Larger households	✓	✓	✓	✓
More adult women in the household	X	✓	✓	✓
More children in the household	✓	✓	✓	✓
Less-educated household heads	✓	x	x	✓
More income sources	✓	✓	✓	✓
Other livestock production (small)	✓	✓	✓	✓
Other livestock production (large)	✓	✓	NS	✓
Crop production	✓	✓	✓	✓
Less off-farm employment/income	✓	✓	✓	✓
More income per capita	NS*	NS	x	x
Income below extreme poverty line	NS	NS	✓	✓
Higher livestock wealth	✓	✓	✓	✓
Higher overall wealth (houses, land, livestock)	NA*	✓	✓	✓
Rural location	✓	✓	✓	✓

Source: Summary results of authors' estimations from HICE(2004-2005), KIHBS(2005-2006), GLSS(2005-2006), and NLSS(2004-2005).
Note: NS = not significant; NA = not applicable.

Households that are larger and have a higher proportion of women and children are more likely to keep above-average-sized flocks. The impact of education on the size of the flock managed is mixed across countries. In Ethiopia and Nigeria, more highly educated households are less likely to keep larger flocks, whereas the opposite is true for Kenya and Ghana. This result may be explained by the fact that households predicted to keep above-average small-scale flocks in Ghana and Kenya keep larger flocks (6 and 11 birds, respectively) and hence would require higher levels of investment (in housing, veterinary inputs, marketing, and so on), which could be undertaken by more highly educated household heads.

As with participation in poultry production, households that have more highly diversified livelihoods portfolios (that is, those with a higher number of income sources or those who are engaged in crop and other livestock production) are more likely to keep above-average-sized flocks. Again, similarly to participation in poultry production, those households located in rural areas (areas with fewer off-farm employment opportunities) are more likely to keep above-average-sized flocks. The evidence, however, is mixed with regard to the income level and the poverty status of the "larger" small-scale producers. In Ghana and Nigeria, those households that have lower income per capita and those that are below the extreme poverty line are more likely to keep above-average-sized flocks, revealing that the livelihoods outcomes of these producers may be affected by HPAI-related supply-and-demand shocks.

Finally, households with higher livestock wealth (across all four countries) and other wealth such as land (across all countries except Ethiopia, where data on wealth were not available) are more likely to keep above-average-sized flocks. Therefore, even though poorer households (in terms of disposable income) may be more likely to keep "larger" flocks in Ghana and Nigeria, these households are wealthier in terms of asset value; hence, combined with their diversified livelihoods portfolios, they may be able to hedge against the HPAI shocks and stresses.

In terms of location, households in Nigeria that are predicted to keep the larger flocks are located in the North West and North Central zones, with about eight birds, followed by the South East and North East zones, with about seven birds. As mentioned above, the South East is a high HPAI risk area, whereas the three northern zones are mid-level HPAI risk areas. In Ghana, households in the Western region keep the largest flocks, with about 13 birds. Western is followed by Volta and Ashanti regions, with 12 birds, and the Central and Eastern regions, with an average of 11 birds. Among those regions, Volta is a high HPAI risk area, whereas the others are mid-level HPAI risk areas, as defined by Stevens et al. 2009.

In East Africa, Kenyan households that are predicted to manage the largest average flocks are located in the Nyanza, Coast, and Western provinces (with around seven birds each). Among these provinces, Nyanza and Western are located in high HPAI risk areas, whereas Coast Province is classified as a mid-level HPAI risk area by Stevens et al. 2009. Finally, in Ethiopia, where the predicted flock sizes are the smallest across the four study countries, households in Tigray, Somale, and Afar provinces are predicted to keep the largest flocks, approximately three birds. Of these three regions, Tigray is classified as a high HPAI risk area and Somale as a mid-level HPAI risk area by the Stevens et al. (2009) risk map. Overall, in both East and West African countries, we see that households located in areas that have higher risks of HPAI spread are more likely to keep household-level, small-scale flocks that are larger than the national average.

Impact of HPAI on Livelihoods of Poultry-producing Households

This study investigates the livelihoods impacts of HPAI supply-and-demand shocks on two livelihoods indicators—namely, livestock income (that is, income from the sales of livestock) and livestock wealth (that is, market value of livestock owned). Data on these indicators are available from the nationally representative household surveys. As mentioned in Section 3, the duration of these shocks on the livelihoods outcomes are assumed to be annual, since the variables used to derive the impact of the shocks (whether or not the household had poultry in the last 12 months, number of poultry owned in the last 12 months, and household total income/expenditure in the last 12 months) are annual, according to the data at hand. Two aspects of these outcomes, namely livestock income and livestock wealth, should be mentioned.

First, livestock income, as a livelihoods outcome, is expected to have impacts on various other livelihoods outcomes, such as current food and nutrition security and gender equality. Likewise, livestock wealth is expected to have impacts on current livelihoods outcomes, such as nutrition from currently owned livestock (eggs or meat), as well as on future livelihoods outcomes, such as future livestock income and future food and nutrition security. Therefore, even though we are focusing on two livelihoods outcomes (income and wealth) due to the availability of nationally representative data on these outcomes, we can argue that these two outcomes are indicators of other important (current and future) outcomes, such as food and nutrition security and gender equality.

Second, it should be noted that HPAI may have indirect impacts (positive or negative) on these livelihoods outcomes through other pathways. For example, livelihoods of households that produce complementary inputs to poultry production (for example, grains such as maize) or those whose members may be employed in sectors that are directly linked to poultry (for example, commercial poultry farms or restaurants) may also be negatively affected by an HPAI-induced shock. Similarly, households that produce other livestock in addition to or instead of poultry (for example, small ruminants or cattle) may experience positive impacts on their livelihoods outcomes if their value increases as a result of substitution effects. In this paper we abstract ourselves from these other possible pathways through which HPAI may affect livelihoods and focus only on poultry production.

As explained previously, to estimate the impact of HPAI on poultry-producing households' livelihoods outcomes, six artificial counterfactual scenarios are investigated. The analysis involves matching households in treatment and control groups for the scenarios described in Table 1 by using the propensity score matching (PSM) method. In each scenario, livelihoods outcomes of a treatment group of households, representing the result of HPAI supply-and-demand shocks, are compared with a control group representing the status quo (no HPAI shocks). The groups are matched according to various household-level characteristics (household demographics, assets, and regional characteristics such as location, poverty status, and number of income sources) expected to affect a household's propensity to be in the treatment situation, as well as the livelihoods outcomes (livestock income and livestock wealth). According to this method, the two groups should differ only in poultry ownership characteristics. The results of this analysis are presented in Table 6.

Table 6. Estimated impact of HPAI on the livelihoods outcomes of household-level poultry producers in the study countries

	Ethiopia	Kenya		Ghana		Nigeria	
Scenarios	**Livestock Wealth, %**	**Livestock Income (Total Income), %**	**Livestock Wealth (Total Wealth), %**	**Livestock Income (Total Income), %**	**Livestock Wealth (Total Wealth), %**	**Livestock Income (Total Income), %**	**Livestock Wealth (Total Wealth), %**
1—All country: lose all poultry	—	—	—	16.9 (0.1)	—	—	—
2—All country: lose all small flocks	—	—	—	—	—	—	—
3—All country: large flocks become small flocks	50.6	27.7 (1.9)	30.5 (0.3)	—	23.3 (4.5)	42.1 (0.6)	—
4—Poultry sellers: high price falls to low price	—	—	—	—	—	—	—
5—High HPAI risk: lose all poultry	—	23 (1.8)—	41.7 (3.2)	21.8 (0.2)	—	—	—
6—Medium HPAI risk: large flocks become small flocks	31.3	—	41.3 (6.3)	29.9 (0.1)	30.8 (4.8)	38.6 (0.7)	20.6(8.5)

Source: Summary results of authors' estimations from HICE(2004-2005), KIHBS(2005-2006), GLSS(2005-2006) and NLSS(2004-2005).

Across scenarios, only the HPAI shocks presented in Scenarios 3 and 6 had significant effects on the livelihoods outcomes of poultry producers in all of the study countries. The insignificant effects (empty cells in Table 6) indicate that the average treatment effect, that is, the impact of the scenario (supply-and-demand shock) on the livelihoods outcome in consideration, is insignificant. This implies that on average, the treated households (those households that would be affected by the HPAI-induced supply-and-demand shock) would not experience any significant losses in their income or wealth from livestock. For example, in either Scenario 2 or in 4, the *average* treated household (which is the average of households with "smaller" small-scale flocks in scenario 2 and the average of households who sell their chickens at higher prices in Scenario 4) would not experience any losses. Similarly, Scenario 1 (*average* small-scale poultry-producing household losing their flocks) resulted in only one significant outcome across study countries. It is likely that within these populations of treated households, some may experience losses. To capture this heterogeneity, we consider "larger" small-scale producers in scenarios 3 and 6, since we expect these to suffer larger losses compared to the average poultry-producing household and the average poultry-producing household with "smaller" small-scale flocks. Consideration of such "larger" smaller-scale producers enabled us to understand that their losses are, on average, significant compared with consideration of all producers as a homogenous group (as in Scenarios 1, 2, and 4).

According to Scenario 3, if an average poultry-producing household that manages a "larger" small-scale flock lost 75 to 85 percent (depending on the country) of its flock due to HPAI, its total livestock wealth would decrease by almost a quarter in Ghana, by almost a third in Kenya, and by half in Ethiopia. This scenario also affects livestock income, reducing it by almost a third in Kenya and by almost half in Nigeria.

According to Scenario 6, in mid-level HPAI risk areas, if an average poultry-producing household that manages a "larger" small-scale flock lost 75 to 85 percent of its birds to HPAI, its total livestock wealth would decrease by one-fifth in Nigeria, by a third in Ethiopia and Ghana, and by almost half in Kenya. The impact of this scenario on livestock incomes of "larger" small-scale producers is significant in Ghana and Nigeria, where these producers may be losing around a third of their livestock income as a result of this shock.

The HPAI shock presented in Scenario 5 had significant impacts on only Kenyan and Ghanaian poultry-producing households' livelihoods outcomes. In Kenya, if all poultry-producing households in the high HPAI risk areas lost all of their flocks, on average they would lose over one-fifths of their annual income from livestock and almost half of their total livestock wealth. In Ghana, this scenario amounts to a reduction in livestock incomes by about one-fifth.

6. CONCLUSIONS AND POLICY IMPLICATIONS

This study investigated the role of poultry in the livelihoods of small-scale household-level poultry producers in four selected SSA countries and the livelihoods impacts that may be caused by the supply-and-demand shocks associated with HPAI outbreaks and scares. The selected SSA countries included Nigeria, Ghana, Kenya, and Ethiopia, which provided a spectrum of countries in terms of HPAI status and the role of poultry in household livelihoods.

Our results revealed that across the four SSA countries, the profiles of households that are predicted to be poultry keepers and those that are predicted to keep "larger"—that is, sized above the national average—small-scale flocks are in fact similar. In each of the study countries, households that are more likely to keep poultry and to keep above-average-sized flocks have less-educated household heads and are larger, with more children and more adult women. These results support previous case studies that found that in these study countries, as well as in other SSA countries, small-scale poultry production is a livelihoods activity mainly undertaken by women and children to meet their immediate cash expenditure needs (for example, school expenses and unexpected health expenditures). These findings have implications for the importance of poultry in intrahousehold gender equality, as well as for development outcomes where incomes managed by women have been found to result in improved outcomes for the family, particularly for children (in terms of health, nutrition, and education). In addition, the elimination of poultry from children's diets as a result of HPAI outbreaks or scares could have nutritional repercussions that ultimately affect their future livelihoods (Iannotti, Barron, and Roy 2008). Detailed household-level livelihoods research on these topics is warranted.

In terms of asset ownership, households that are predicted to be poultry keepers and those that are predicted to keep "larger" above-average-sized flocks have higher average values of livestock wealth and other assets (for example, land). Moreover, these households have more diversified livelihoods strategies, as is evident from their significantly higher numbers of income sources and participation in other agricultural livelihoods activities (crop production and other livestock production). Therefore, for predicted poultry-keeper households and for households that are likely to keep "larger" flocks, poultry is one of several livelihoods strategies/assets geared toward building resilience against shocks. Thus, these households are likely to be resilient against HPAI-related supply-and-demand shocks.

To estimate the impact of HPAI on poultry-producing households' livelihoods outcomes (income and asset wealth), especially those pertaining to livestock, six artificial counterfactual scenarios were created and investigated: (1) 100 percent loss of poultry flock, (2) 100 percent loss of small-scale poultry flocks, (3) 75–85 percent loss (depending on the country model) in "larger" small-scale poultry flocks, (4) 50 percent reduction in poultry price, (5) 100 percent loss of poultry flock in high-risk areas, and (6) 75–85 percent loss (depending on the country model) in "larger" small-scale poultry flocks in mid-level risk areas.

We used the propensity score matching method to assess the impacts of these six shocks on the livelihoods outcomes (income and asset wealth) of poultry producing households. Our results reveal that across all four study countries, households with "larger" small-scale flocks are more vulnerable to HPAI in terms of livestock income loss, livestock wealth (asset value) loss, or both. When converted into the total income or total wealth loss, we find that, depending on the scenario, country, and disease risk level of the area in which the households are located, the magnitude of loss in total asset value and total annual household income reveals that small-scale poultry-producing households that keep larger flocks stand to lose the most from HPAI-related shocks (Table 6). Furthermore, according to the disease spread risk maps developed by Stevens et al. (2009) for the study countries, a great majority of these small-scale producers with larger flocks are located in the medium to high HPAI spread risk areas. Therefore, these households seem to be most vulnerable to HPAI-related shocks.

Given the magnitude of loss in assets and income for the poultry-producing households with "larger" small-scale flocks and the important role of poultry in the sustainability of future livelihoods (through intrahousehold gender equality and nutrition), targeted intervention measures should be in place to encourage the adoption of HPAI mitigation measures. In particular, households with "larger" small-scale flocks should be given special focus when designing preventive, training, and compensation programs. Even though households with larger flocks are found to have diversified agricultural livelihoods strategies, further diversification of farming activities, as well as investment in other nonfarm activities, should also be emphasized to help minimize adverse effects of HPAI shock on the livelihoods of the households.

Policy measures to support capacity building and create incentives for investment in poultry production, especially in biosecurity, are of fundamental importance for the strengthening of the small-scale poultry sector against shocks such as HPAI. Because households that manage larger flocks are more likely to have less-educated household heads, their training and education in biosecurity and better poultry production is of paramount importance for disease risk reduction and is likely to result in high marginal returns. Moreover, since households with higher proportions of children are found to be more likely to keep poultry and to manage larger flocks, schoolchildren in particular could be an entry point for efforts to improve biosecurity levels in the country. Similarly, given their role in poultry rearing, women should also be encouraged to be actively involved in training programs and in dissemination of information regarding biosecurity technologies.

Finally, our results have implications for other shocks to livelihoods, whether through livestock diseases or in general. Our study revealed that a greater proportion of poultry keepers are in rural areas, have diversified agricultural livelihoods strategies (including crop and other livestock production), and have associated wealth (land and other livestock). Therefore, an idiosyncratic shock that affects only one of the many agricultural livelihoods strategies they may practice (in this case, poultry production) and/or one of the several livelihoods assets they may own (for example, poultry flock) should not have as significant an effect on the overall livelihoods outcomes as covariant shocks (such as draughts), which may affect several of the livelihoods strategies and assets at once. The framework and data presented in this paper would be suitable for the analysis of idiosyncratic shocks (such as livestock or crop diseases); however, more dynamic frameworks and analyses are required to study the impact of covariant shocks on household-level livelihoods outcomes.

APPENDIX: SUPPLEMENTARY TABLES

Table A.1. Summary of probit models in study countries (determinants of participation in poultry production)[1]

Household, farm, and regional characteristics	**Ethiopia (N = 15,374)**	**Kenya (N = 12,640)**	**Ghana (N = 5,531)**	**Nigeria (N = 6,443)**
Age of head of household	–0.003** (0.002)	0.177*** (0.032)		
Age of head of household squared	0.000** (0.000)	–0.001*** (0.000)		
Skill of head of household (age–years of schooling–5 years)		0.0183*** (0.004)	0.000 (0.001)	–0.001 (0.002)
Skill of head of household squared		–0.012** (0.001)	0.000 (0.000)	0.000 (0.000)
Years of education of head of household		0.0461*** (0.013)	–0.014*** (0.004)	–0.001 (0.006)
Years of education of head of household squared		–0.0018 (0.001)	0.001*** (0.000)	0.000 (0.000)
Household size	0.003 (0.002)	0.0264** (0.010)	0.011*** (0.003)	0.008*** (0.003)
Proportion of females in household with age above 15 years old	–0.046** (0.022)	0.4132*** (0.105)	0.016 (0.021)	0.054 (0.003)
Proportion of household members with age below 18 years old	–0.025 (0.023)	0.1357 (0.117)	–0.006 (0.027)	0.119*** (0.033)
Number of income sources	0.005 (0.010)	0.6553*** (0.02)	0.091*** (0.005)	–0.003 (0.007)
Household engages in nonfarm income-generating activities, dummy		–0.7637*** (0.047)	–0.164*** (0.013)	
Number of plots	0.052** (0.002)			
Livestock wealth (excluding poultry)	0.000 (0.000)			
Wealth (house, land, livestock, and durable assets)			0.000 (0.000)	0.000 (0.000)
Household has pack animals (donkey, horse, and/or mule), dummy	0.097*** (0.010)			
Household raises cattle, dummy				0.045 (0.034)
Household raises small livestock (goat or sheep), dummy	0.160*** (0.009)			

Table A.1. Continued

Household, farm, and regional characteristics	Ethiopia (N = 15,374)	Kenya (N = 12,640)	Ghana (N = 5,531)	Nigeria (N = 6,443)
Household raises sheep, dummy				0.170*** (0.027)
Household raises goat, dummy				0.597*** (0.018)
Household in rural area, dummy	–0.125* (0.069)		0.029* (0.017)	0.192*** (0.013)
Household is core/extremely poor, dummy	–0.027 (0.023)	–0.3762*** (0.107)	–0.135*** (0.043)	–0.086 (0.060)
Rural and core/extremely poor	0.153** (0.069)	0.3343** (0.116)		–0.006 (0.083)
Density of poultry population in district	0.663*** (0.058)	0.5340*** (0.118)	0.414*** (0.049)	0.437*** (0.053)

Source: Authors' estimations from HICE(2004-2005), KIHBS(2005-2006), GLSS(2005-2006), and NLSS(2004-2005).
Note: Significance levels: ***p < 0.01; **p < 0.05; *p < 0.1.
[1]Marginal effects are presented; regional dummies were excluded from the table due to space concerns; please see Ayele et al. 2010, Mensa-Bonsu et al. 2010, Ndirangu et al. 2010, and Okpukpara et al. 2010 for detailed tables of these models.

Table A.2. Summary of count models (ZINB) in study countries (determinants of poultry flock size)[1]

Household, Farm, and Regional Characteristics	Ethiopia (N = 18,507)	Kenya (N = 12,627)	Ghana (N = 1,683)	Nigeria (N = 6,443)
Age of head of household[1]	–0.0055 (0.009)	0.177*** (0.032)		
Skill of head of household (age–years of schooling–5 years)			0.00 (0.091)	0.046** (0.018)
Education years of head of household[1]		0.129*** (0.046)	–0.25 (0.241)	–0.021 (0.067)
Size of household	0.0150 (0.013)	0.427*** (0.038)	0.84*** (0.155)	0.200*** (0.054)
Proportion of females in household with age above 15 years old	–0.2670 (0.126)	–2.457*** (0.478)	–2.82* (1.704)	1.007** (0.485)
Proportion of household members with age below 18 years old	–0.0420 (0.119)	–0.857** (0.400)	–4.75*** (1.639)	2.308** (0.627)
Proportion of household members with age between 6 and 14 years old				
Number of income sources	–0.0556 (0.050)	3.685*** (0.118)	–0.28 (0.309)	–0.106 (0.072)
Household engages in nonfarm income-generating activities, dummy			0.47 (0.857)	
Household has access to formal credit				2.117** (1.231)
Livestock wealth (excluding poultry)	0.0001*** (0.000)			

Table A.2. Continued

Household, Farm, and Regional Characteristics	Ethiopia (N = 18,507)	Kenya (N = 12,627)	Ghana (N = 1,683)	Nigeria (N = 6,443)
Household has pack animals (donkey, horse, and/or mule), dummy	1.1226*** (0.066)			
Household raises cattle, dummy				0.499** (0.256)
Household raises small livestock (goat or sheep), dummy	1.0714 (0.054)			
Household raises sheep, dummy				4.390 (0.740)
Household raises goat, dummy				9.548 (0.560)
Household in rural area, dummy	–0.2174 (0.449)		1.34 (0.796)	
Household is core/extremely poor, dummy	0.0188 (0.117)	1.345*** (0.442)	0.40 (3.592)	–0.510 (0.820)
Rural and core/extremely poor	0.116 (0.448)	0.432 (0.610)		0.216 (1.034)
Density of poultry population in district	4.3154 (0.340)	0.675** (0.332)	–1.00*** (2.187)	8.315 (1.115)
Zero observations	9,877	7,629	300	4,652
Nonzero observations	8,630	4,998	1,683	17,91
Vuong test, z-value	29.66***	34.24***	7.11***	32.90***

Source: Authors' estimations from HICE(2004-2005), KIHBS(2005-2006), GLSS(2005-2006) and NLSS(2004-2005).
Note: Standard errors are presented in brackets; significance levels: ***p < 0.01; **p < 0.05; *p < 0.1.
[1]Marginal effects are presented; regional dummies were excluded from the table due to space concerns; please see Ayele et al. 2010, Mensa-Bonsu et al. 2010, Ndirangu et al. 2010,and Okpukpara et al. 2010 for detailed tables of these models.
[2]Squared variables of age, education, and skill were also estimated but yielded estimates that were not statistically significant and were omitted.

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