International Scholars Journals

African Journal of Dairy Farming and Milk Production ISSN 2375-1258 Vol. 6 (8), pp. 001-014, August, 2019. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Economywide impact of Avian influenza in Ghana – A dynamic computable general equilibrium (DCGE) model analysis

Xinshen Diao

Development Strategy and Governance Division, IFPRI, 2033 K Street, NW Washington DC 20006, USA.
E-mail: x.diao@cgiar.org Tel: (o) 202-862-8113. Fax: 202-467-4439.

Accepted 08 May, 2019

A dynamic computable general equilibrium (DCGE) model is used to quantitatively assess the economywide impact of HPAI in Ghana. The likely effect of an Avian influenza outbreak is modeled as demand or supply shocks to the poultry sector. The analysis shows that while the chicken sector is quite a small sector of the Ghanaian economy, the shock in chicken demand due to consumers' anxieties is the dominant factor causing the fall of chicken production. The indirect effect on soybean and maize that are used as chicken feed is also large. Under the worst-case scenario, soybean production will fall by 37% and maize by 6.4%. However, the economywide impact on both agricultural gross domestic product (GDP) and GDP is very small. In the worst-case scenario, in which chicken production falls by 70% in 2011, agricultural GDP falls by only 0.47% and GDP is almost unchanged. However, the livelihood impacts of a HPAI outbreak could be significant for some sections of the population in Ghana particularly those involved in the poultry sector. Micro-level analysis of chicken producers' livelihood, therefore, is necessary.

Key words: Avian influenza, general equilibrium, Ghana.

INTRODUCTION

Avian influenza is a zootomic disease that has shown to be capable of producing fatal disease in humans. As part of the HPAI research project for Southeast Asia and Africa, the primary goal of this paper is to provide a quantitative assessment of the economywide impact of HPAI in Ghana under different scenarios. A dynamic computable general equilibrium (DCGE) model for Ghana has been developed for this study, and a recent (2005) social accounting matrix with a detailed production structure at both national and subnational levels is used as the data set for this analysis.

Like many other West African countries, Ghana has a diversified agricultural economy. At the national level, the agricultural sector accounts for 35% of gross domestic product (GDP) (Table A1 in Appendix). Within agriculture, root crops compose the largest subsector, accounting for 8.7% of GDP (almost one-fourth of agricultural GDP (AgGDP)). The second largest agricultural subsector is staple crops other than cereals and root crops, which includes plantains, pulses, and oilseed crops. This subsector accounts for 8.3% of GDP (equivalent to 23.6% of AgGDP). Livestock, including poultry, cattle, sheep, goats, and other livestock products, actually is the smallest subsector in agriculture, after export crops (6.5%), fishery and forestry (5.7%), and grain crops (3.3%), and accounts for 2.5% of GDP (equivalent to 7.1% of AgGDP).

Within agriculture, poultry sector, including chicken broilers, layers, and eggs, accounts for 1.1% of AgGDP and 2.3% of agricultural production, and less than one-third of the production of the livestock subsector (Table A2 in Appendix). With a relatively low (20%) tariff on chicken imports, domestic broiler production is hardly competitive with chicken imported from other developing countries, such as Thailand and Brazil. Thus, imports of broiler chicken meet about 77% of domestic demand (Table A2 in Appendix). However, domestic demand for eggs is mainly met by domestic supply. Thus, the chicken industry in Ghana, particularly among commercial chicken farmers, is dominated by layers and egg production, which accounts for more than 95% of chicken production in the country.

While the chicken industry is a relatively small sector in the Ghanaian economy, its importance varies at the subnational level. As shown in Table A3 in Appendix, chicken production is relatively more important in the Coast zone, accounting for 7.7% of zonal-level agricultural production. In contrast, chicken accounts for only 0.5% of South Savanna agriculture and 2.1% of North Savanna agriculture. While the share of chicken in agricultural production is the highest in the Coast zone among the four zones, in terms of national total chicken production the Forest zone is the most important, accounting for 39% of national chicken production (Table A3 in Appendix). The reason is that the Forest zone is the most important agricultural production area in Ghana, while the Coast is the least important, though this zone is the most important nonagricultural center (with the capital city, Accra, being located in this zone).

In order to quantitatively measure the economywide impact of HPAI in Ghana, a dynamic computable general equilibrium (DCGE) model for Ghana has been developed for this study, and a recent (2005) social accounting matrix with a detailed production structure at both national and subnational levels is used as the data set for this analysis. The analysis based on a series of model simulation scenarios shows that, while chicken is a quite small sector of the Ghanaian economy, the shock in chicken demand due to consumers' anxieties is the dominant factor in causing chicken production to fall. The indirect effect on soybean and maize that are used as chicken feed is also large. Under the worst-case scenario, soybean production will fall by 37% and maize by 6.4%. However, the economywide impact on both agricultural GDP and GDP is very small. In the worst-case scenario, in which chicken production falls by 70% in 2011, agricultural GDP falls by only 0.4% and GDP is almost unchanged. However, the livelihood impacts of a HPAI outbreak could be significant for some sections of the population in Ghana particularly those involved in the poultry sector. Micro-level analysis of chicken producers' livelihood, therefore, is necessary.

ANALYTIC METHOD AND DATA

The model

A general equilibrium model is the proper tool for analyzing any economywide impact of agricultural production, trade, or demand shocks, as such a model captures the economic interlinkages between agriculture and the rest of a country's economy. The DCGE model applied in this study is an extension of a static, standard DCGE model that was developed in the early 2000s at International Food Policy Research Institute (IFPRI) and has been documented in Lofgren (2001). The recursive dynamic version of the DCGE model is based on this standard DCGE model, with the incorporation of a series of dynamic factors. The early version of this DCGE model can be found in Thurlow, (2004), while its recent applications include the two country case studies, Zambia and Uganda, in Diao et al. (2007). The Ghana DCGE model was first developed for analyzing economic transformation (Breisinger et al., 2008, 2009), and agricultural development in Ghana in order to support the Comprehensive Africa Agriculture Development Program (CAADP) roundtable in Ghana (Breisinger et al., 2009). Similar to the other DCGE models, the Ghana DCGE model is an economywide, multisectoral model that solves simultaneously and endogenously for a series of economic variables, including commodity and factor prices. However, unlike traditional DCGE models that focus on national economies with multiple production sectors, the Ghana DCGE model considers subnational heterogeneity in agricultural production by assigning a series of different production functions for producing a similar agricultural product, for example, maize or poultry, to different regions. The setup for such a model requires more information about a country's agricultural production than does a traditional DCGE model—for instance, information about the distribution of land across regions for each type of crop or livestock production, which significantly increases the complexity of calibrating the model to the real economy. However, once such information is available and the model is constructed according to it, the model can better capture the economic interlinkages at both subnational and national levels, including both the interlinkages across regions and those between sectors.

Like any other DCGE model, the DCGE model captures, with its general equilibrium feature, economic activities on both demand and supply sides. On the supply side, the model has defined specific production functions for each economic activity, and such economic activity can be agricultural production, for which the functions are defined at the subnational level, or nonagricultural production, which is defined at the national level. As in any other quantitative economic analysis, certain assumptions must be applied before calibrating the model to the data. In a typical DCGE model, a constant return to scale technology with constant elasticity of substitution (CES) between primary inputs is a fundamentally necessary assumption in order for the model to have a general equilibrium solution. However, as both primary and intermediate inputs are considered in the production functions of a DCGE model, a Leontief technology with fixed input-output coefficients is often assumed for the use of intermediate inputs, such as fertilizer and seeds in crop production, feed in poultry production, and raw materials in the food processing industry, as well as for the relationship between intermediates and primary inputs in aggregation.

The demand side of the DCGE model is dominated by a series of consumer demand functions. The system of consumer demand functions is solved by maximizing a stone-geary utility function in which the income elasticity does not need to be one (which is different from a Cobb-Douglas utility function), and, hence, the marginal budget share for each consumer good departs from the average budget share of this good in consumers' total budgets.[1] With such a utility function assumed, information on income elasticity is required in order to calibrate the demand system to the data. We will discuss this in detail later, together with the discussion about the data and other parameters applied in the model. As in any other general equilibrium model, consumers' income that enters the demand system is an endogenous variable. Income generated from the primary factors employed in the production

[1] Marginal budget share (MBS) relates the allocation of incremental income spent on different consumption goods for a consumer, while average budget share (ABS) is the current (total) budget allocation among different goods. For example, a consumer currently spends 2% of his or her income on chicken consumption, indicating that the ABS for chicken is 2%. When this consumer's income increases in the next year, for each increased dollar of income he or she prefers to spend 3 cents on chicken. In this case, the value of the MBS for chicken is 3% . When the MBS is greater than the ABS for a particular consumption good (in this case, chicken), demand for this good is called income elastic. However, if the MBS value is lower than the ABS for a particular good, for example, sorghum, demand for this good (sorghum) is said to be income inelastic.

process is the dominant income source for consumers, while income coming from abroad (as remittances received) or the government (as direct transfers) is also considered.

The relationship between supply and demand must be explicitly modeled in a DCGE model, and such a relationship determines the equilibrium prices in the domestic markets. Given that a DCGE model also captures the trade flows, both import and export, the relationship between domestic and international markets is also modeled explicitly. Generally speaking, any commodity produced or consumed in the domestic market can also be an exported or imported one. However, in a DCGE model, the commodities produced or consumed in the domestic market are not perfectly substitutable for those going to or coming from international markets. Because of this assumption, the international price for any product, regardless of whether this product is exportable or importable, cannot be fully transmitted into domestic markets, and changes in domestic supply and demand will finally determine its price. However, if a product is exportable or importable, its price in domestic markets can be affected by international prices and by export and import demands. To capture such linkages with international markets, the model assumes price-sensitive substitution (imperfect substitution) between foreign goods and domestic production. With such an assumption, if domestic demand increases more than the supply of this good, the domestic price for this good rises relative to the imports and exports prices. Exports of this good fall and imports rise. However, if productivity improves in domestic production and rising supply outpaces the increases in demand for the product, the domestic price then falls relative to the border prices, and exports rise and imports fall. Imperfect substitution also implies that agricultural productivity improvement by itself may not be enough to expand agricultural exports, and improving marketing conditions is also necessary.

While the linkages between demand and supply through changes in income (an endogenous variable) and productivity or land expansion (often exogenous variables) are the most important general equilibrium interactions in an economywide model, production linkages also occur across sectors through the intermediate demand and competition for primary factors employed in production sectors. Many primary agricultural products need to be processed before reaching consumers and export markets. Food processing is often an important component of the manufacturing sector in developing countries. Growth in the agricultural sector can stimulate growth in food processing by providing cheap inputs (forward linkages) and creating more demand for processed goods (backward linkages through rising income of farmers). Conversely, growth in an export-oriented agricultural product, for example, cocoa in Ghana, often creates increased demand for processing that product. Although most of such processing activities are very simple, with low value addition, they increase labor demand and hence create job opportunities for both rural and urban households.

Investments affect production over time, and productivity growth is a gradual process. Capturing such a dynamic process is a key component of the DCGE model. Given the complexity of the model setup for Ghana, measured both in the large number of production sectors in agriculture and nonagriculture and in the disaggregated agricultural production and household groups across subnational regions, it is unrealistic to expect a fully developed intertemporal general equilibrium model for this study[2]. Thus, the recursive dynamics are applied in the model. With such a model setup, the dynamics occur only between two periods, and consumption smoothing along the growth path, as well as intertemporal investment and saving decisions, are not taken into account. Instead, private investment and hence capital accumulation are determined by a Solow type of saving decision in which savings are proportional to income and not endogenously solved from a Ramsey type of intertemporal utility function[3]. Moreover, population growth, land expansion at the subnational and national level, and productivity growth are all exogenously determined.

The government is generally included in a DCGE model as an institutional account. In the Ghana model, the government collects taxes (which include tax revenue from domestic households and producers, export taxes, and import tariffs), transfers part of this income to households, and uses the rest either for investment or recurrent spending. As in many other sub-Saharan African countries, a major part of the government's spending in Ghana is financed by international or developed-country donors, and in the model it is captured as a transfer to the government from abroad. Mathematical presentation of the DCGE model for Ghana can be found in Breisinger et al. (2009).

The 2005 social accounting matrix for Ghana

The key data set used in any DCGE modeling analysis is called a social accounting matrix (SAM). The 2005 SAM for Ghana was constructed by Breisinger, Thurlow, and Duncan (2007). This SAM includes 71 production sectors/commodities, including 28 in the agricultural sector, 33 in the industrial sector, and 10 in the service sector (Table 1). The SAM (and hence the model) also explicitly defines 28 agricultural subsectors at the four agro-ecological zonal levels. Broadly speaking, the Coast zone covers the Eastern and Volta regions; the Forest zone includes the Ashanti, Western, and Central regions; the South Savanna comprises Brong Ahafo and part of Volta; and the North Savanna zone includes the Upper West, Upper East, and Northern regions. Because of this, there are 155 (28 x 4 + 33 + 10) production activities.

The demand side of the SAM and the model consists of 90 representative household groups, 50 in the urban areas of the four zones and Greater Accra and 40 in the rural areas of the four zones. These 90 representative households correspond to 10 population deciles (in which each decile corresponds to 10% of the population) ranked according to the level of per capita income, from low to high. That is to say, within each zone there are 10 rural and 10 urban household groups, together with 10 urban groups in Accra. For each of the four zones, the 20 household groups (and 10 in Accra) are ranked from 1 to 10 corresponding to the 10 national population deciles. Households earn their incomes from factors employed in both agricultural and nonagricultural production. These factors include family labor employed only in local agricultural production, unskilled labor that is mobile and employed in both agricultural and nonagricultural activities, capital employed in both agricultural and nonagricultural production, and land that can be reallocated across crops within the zone. While rural households can also earn incomes from participating in nonagricultural activities, we assume that urban households earn incomes solely from nonagricultural activities.

Parameters and elasticities applied in the DCGE model

Any analysis based on a model with a system of equations depends critically on the elasticities and parameters employed in the model. However, unlike most partial equilibrium models in which supply and demand functions are constructed as elasticity-based functions, in a DCGE model well-behaved structural functions that are solved by maximizing profits on the producer side and

[2] An intertemporal general equilibrium model in literature is often used with a relatively aggregated economic structure. See Diao et al. (2005) for the growth linkage analysis in the case of Thailand.

[3] See Diao et al. (1998) for the discussion of Ramsey-type intertemporal utility functions and their role in the determination of consumers' consumption and saving behaviors.

Table 1. Sectors/commodities in Ghana SAM and DCGE model

Agriculture	Industry	Services
Cereal crops	**Mining**	Trade services
Maize	Gold	Repairing, hotel and restaurant
Rice	Other mining	Transport services
Sorghum and millet	**Food processing**	Communication
Other cereals	Formal food processing	Banking and business services
Root crops	Informal food processing	Real estate
Cassava	Cocoa processing	Community and other services
Yams	Sugar	Public administration
Cocoyams	Dairy products	Education
Other staple crops	Meat and fish processing	Health
Cowpea	**Other agriculture-related processing**	
Soybean	Textiles	
Palm oil	Clothing	
Groundnuts	Leather and footwear	
Tree nuts	Wood products	
Fruit, domestic	**Other manufacturing**	
Vegetable, domestic	Paper products, publishing and printing	
Plantains	Crude and other oils	
Other crops	Petroleum	
Export crops	Diesel	
Fruit, export	Other fuels	
Vegetable, export	Fertilizer	
Cocoa beans	Other chemicals	
Export industrial crops	Rubber and other industrial products	

maximizing welfare on the consumer side are employed. In this way, the parameters capturing the economic structure and factor intensity at the sector level (in our case at the sector and zonal level) play more important roles in determining the model results than elasticities do. All these parameters must calibrate to the data, together with the predetermined elasticities.

Specifically, the substitution elasticity between primary inputs in the CES production function must be assumed or chosen from the literature, as any country's data set used to construct a DCGE model is generally unable to support an econometric estimation for obtaining such elasticity for the entire production system that will be included in the model. For example, if a Cobb-Douglas (CD) technology is chosen as the production structure of a DCGE model, it then implicitly assumes a unit elasticity of substitution between primary inputs (for example, labor, land, and capital) in the production functions. In this way, other parameters in the CD production function of the model (for example, the marginal product of each input, the key parameter in this type of function) can be directly calibrated using the country data of the SAM (that is the share of value-added for each input employed in the total value-added of this sector). In the DCGE model, a CES function form (other than CD technology) is chosen. The elasticity in the production function is predetermined and drawn from DCGE literature about other African countries. The other parameters in the production functions of the model are then calibrated using the data composed in Ghana 2005 SAM. Also, we decided to use similar substitution elasticity in the production functions for each production sector across four zones. However, because of the difference in factor intensity across sectors and sectoral structure across zones, heterogeneity in technology for producing a similar product is captured by calibrating the other parameters of the production function to such disaggregated data.

Besides primary inputs, intermediates are also employed in the production process. With the assumption of Leontief technology in the use of intermediates, a set of fixed input-output coefficients is applied in the production function, and these coefficients are directly calibrated using the data of the Ghana SAM.

With a stone-geary type of utility function applied in the model, the marginal budget share (MBS) is the parameter applied in the demand system of the model. While the average budget share (ABS) for each individual commodity consumed by each individual household group can be directly calculated using the data of the Ghana SAM, the income elasticity of demand must be obtained to derive a series of MBSs. For this study, the income elasticity is estimated from a semi-log inverse function suggested by King and Byerlee (1978) and based the data from Ghana Living Standards Survey 5 (GLSS5 2005/06). The estimated results show that demand for poultry is income elastic with an income elasticity of 1.25, while for many staple foods this elasticity is less than 1. While we estimate the income elasticity for rural and urban households as only two groups, because of different budget shares spent on the same product (for example, chicken) across 90 household groups, the MBSs and hence price elasticities can be different across household groups. As in other DCGE models, income and price elasticities are not directly used in the demand system, which composes a series of structural functions in the model.[4]

[4] The implicit price elasticities can be derived from the structural demand functions used in the DCGE model. For cross-price elasticities, they depend on both marginal and average budget shares, subsistence parameters, and prices, while for their own price elasticities they depend also on the level of income. The mathematical process to derive these price elasticities using the parameters and variables included in the DCGE model can be obtained upon request from the author.

Limitations of the DCGE model

Like any other economic model, the DCGE model has its limitations. There are at least four limitations or caveats that are important when interpreting the results. The first caveat is on the demand side. While income elasticities of demand in the model are econometrically estimated and subsistence consumption is taken into account in the demand functions, the use of a linear expenditure system (LES) to specify household demand can only partially capture demand dynamics. MBSs, and hence the income elasticity in such a demand system, remain constant over time. While rapid demand shifts can be better captured by using an implicit direct additive demand system (AIDADS) (Yu et al., 2003) or by applying latent separability (Gohin, 2005), the highly disaggregated demand structure in the model constrains our choice of methods. Second, as in most other DCGE models, production technologies that are calibrated to the initial economic structure remain constant over time. Because of this, the model simulations do not capture the effects of substantial technological changes and innovations that are embodied in new investments, especially foreign direct investments. Third, the existence of externalities and spillovers indicates that the social value of new investments can greatly exceed their private value, but the model does not capture increasing returns to scale, technological externalities, and spillovers, and may therefore underestimate the contribution of growth in nontraditional and import-substitutable agriculture and of new manufacturing activities during a rapid growth period.

While an economywide DCGE model can better capture the potential impact of an Avian flu outbreak on both producers and consumers as well as on domestic market prices and trade in a consistent framework, there are certain limitations for using such a model to analyze a specific agricultural subsector that is relatively small in a country's economy. As shown in the previous analysis, poultry accounts for a very small share of AgGDP and consumption of households in Ghana. Because of this, one cannot expect any significant economywide impact of Avian flu outbreaks in the country, though the local effect may be relatively large in some areas and for some types of farmers or consumers. To address this caveat, the economywide analysis needs to be combined with micro-level analysis at the household and local economic level. Thus, under this project, a household-level analysis, using the GLSSV data similar to that used to develop the SAM for Ghana, has been conducted. When these two reports are read together, the research results of the two studies are shown to be complementary. Bearing these caveats in mind, the DCGE model can still provide useful simulations to assess the effects of Avian flu within the context of a broader economic system. Thus, with all the parameters and data of the Ghana SAM discussed above, the DCGE model is ready to conduct simulation analysis. We first discuss the simulations that we plan to perform using this model.

The model scenarios

Three HPAI outbreaks were reported in Ghana in April to June 2007 in various locations across three regions (Aning et al., 2008). While the direct production impact is relatively local, with all chickens being slaughtered in affected areas as a control measure, demand shock is often nationwide because of consumers' anxieties about health risks from HPAI-affected chicken. In assessing the impact of a HPAI shock, following Vanzetti, (2007) we assume that an outbreak will directly lower chicken production by 10% in the country. The first three scenarios are designed to capture the effect of such direct production shocks. We introduce the production shock in the fourth year of the model, which corresponds to the year 2009 (2005 is the initial year of the model, which runs from 2006 to 2011). In the first scenario, we reduce capital stock (which represents the stock of chicken for production) in the chicken sector such that production falls by 10% in 2009 from the same year's level in the base run, and then production returns to the base-run level of growth in 2010 and 2011. In the second scenario, we consider a slow recovery situation in which production will only recover in 2011, while in the third scenario we consider that production will stay at its 2009 level through 2011. Scenarios 4 to 6 are designed for the demand shocks. In Scenario 4, in addition to the assumptions used in Scenario 1, the MBS for chicken in the demand function is lowered in 2009 such that national chicken consumption is reduced by 40% compared with 2009's base run. Similarly, Scenario 5 is for additional demand shock from Scenario 2, and Scenario 6 is for additional demand shock from Scenario 3. Table 2 summarizes these six scenarios and their assumptions and targeted direct effects. In reality, consumers' response to HPAI seems to diminish with time. For example, instead of the same 40% decline in demand, we can assume a decline of 30 or 20%. Given that there are so many possibilities in terms of consumers' response after the first year's shock, we decide to use the same shock imposed in Scenario 4 for Scenarios 5 and 6. Hence, we can treat these two scenarios as the worst-case ones following an outbreak of HPAI. Even though the shocks considered are arbitrary, we want to emphasize that the nature of results is driven largely by the structure of the poultry sector in Ghana and not so much by the magnitude of the shocks. This was the rationale for us choosing the levels of shocks. Our conjecture was that given the structure, with the shocks to the poultry sector there is likely to be no first order effect on the aggregate economy. If insignificant effects are derived from reasonably large shocks then with smaller shocks there is likely to be even more insignificant economy wide effect in Ghana. The structure of the poultry sector is the main factor that limits economy wide impacts (where economy is spanned by the model) if an outbreak of HPAI were to occur. However, for identical reasons that limit the economy wide impact, the livelihood impacts of a HPAI outbreak could be significant for some sections of the population in Ghana particularly those involved in the poultry sector.

DISCUSSION OF THE DCGE MODEL RESULTS

Demand shocks dominate the impact on chicken production and imports

Under all six scenarios, the direct effect is always on chicken production. Moreover, given that Ghana is unable to export chicken even in a normal situation, with an outbreak of HPAI the demand-side effect seems to be a more dominant factor in causing chicken production to fall. When demand is reduced by 40% in 2009, chicken production falls slightly more than 40% (at 41.6%). The model assumes the existence of imperfect substitution between imports and domestic production. Under this assumption, domestic production falls more than the declines in imports that will be discussed later. Figure 1 summarizes the direct impact on chicken production. We measure such impact in real terms of million cedis so that the results can be compared with the impact on chicken production revenue reported in Figure 2.

Comparing Figures 1 and 2, we can see relatively larger differences between production and revenue effects when demand shock is ignored. With reduced production and without demand shock, prices rise with a shortage in supply, which results in less reduction in

Table 2. Summary of the DCGE model scenarios.

Scenarios	Assumptions imposed	Targeted direct impact
Base run	Exogenous growth in population, land, productivity	GDP, AgGDP growth rates similar to those in 2000 to 2005
Scenario 1	Lowering capital stock in chicken production in 2009; other assumptions same as in base run	Reducing chicken production by 1% from base run's 2009
Scenario 2	Lowering capital stock in chicken production in 2009 and 2010; other assumptions same as in base run	Reducing chicken production by 10% from base run's 2009 to 2010
Scenario 3	Lowering capital stock in chicken production in 2009 to 2011; other assumptions same as in base run	Reducing chicken production by 1% from base run's 2009 to 2011
Scenario 4	Lowering marginal budget share for chicken consumption in demand function in 2009; other assumptions same as in Scenario 1	Reducing chicken demand by 40% from base run's 2009
Scenario 5	Lowering marginal budget share for chicken consumption in demand function in 2009 to 2010; other assumptions same as in Scenario 2	Reducing chicken demand by 40% from base run's 2009 to 2010
Scenario 6	Lowering marginal budget share for chicken consumption in demand function in 2009 to 2011; other assumptions same as in Scenario 3	Reducing chicken demand by 40% from base run's 2009 to 2011

chicken production revenue (Figure 2) than in production (Figure 1). However, when a demand shock is imposed in Scenarios 4 to 6, in addition to the production shock, chicken prices stop rising and the declines in chicken production directly become similar declines in chicken production revenue (Figure 2). We did not observe a significant decline in chicken prices in Scenarios 4 to 6 because both demand and production fall at a similar rate. Thus, a similar level of prices as before is the result of a much lower level of supply and demand at the new equilibrium for the chicken market.

As we mentioned above, about 50% of the chicken consumed in the domestic market in Ghana is supplied through imports. While an HPAI outbreak occurs only among the domestic chicken production, demand for all kinds of chicken, whether imported or domestically produced, falls due to consumers' panic and concerns. Figure 3 captures such a situation. Here we report only two extreme scenarios, together with the base run: Scenario 3, in which chicken production falls by 10% between 2009 and 2011 from the same year's level in the base run, and Scenario 6, in which an additional 40% decline in chicken demand occurs in 2009 to 2011.

As shown in Figure 3, without a consumer-side shock, imports of chicken rise to fill the market gap caused by the decline in domestic production. However, when consumers start to respond to an HPAI outbreak, imports fall along with domestic production. Declines in imports, in the absolute term, are generally smaller in magnitude than declines in domestic production, which causes the ratio of imports to total consumption to rise (Figure 4). As shown in Figure 4, with a 10% decline in domestic production of chicken and without consumers' response to the HPAI shock, the imports-to-consumption ratio rises to 0.67, from the base run's current ratio of 0.46 all reported in the model for the year 2011. However, when consumers start to respond and lower their demand by 40%, the imports-to-consumption ratio falls to 0.58, which is still higher than the base run's 0.46.

Indirect effects of HPAI outbreak

The main purpose of applying the DCGE model in this study is to assess the indirect effects of an HPAI outbreak, through the linkages of the chicken sector with the rest of the economy. Chicken production, particularly on commercial chicken farms, employs maize as feed, combined with soybeans and other protein stuffs such as fish meal. Declines in chicken production promise to affect maize and soybean production more than any other aspect of the economy. The DCGE model indeed captures such a linkage effect. As shown in Figures 5 and 6, both maize and soybean production are affected, and the negative effect from the demand shock is again greater. If chicken production falls by 10%, then maize and soybean production fall by 1.0 and 5.4%, respectively (Table 3, Column 1 of the second part). When chicken production declines by 41.6% as a result of a 40% reduction in chicken demand, maize and soybean production fall by 3.7 and 22.2%, respectively (Table 3, Column 4 of the second part). The longer the period in

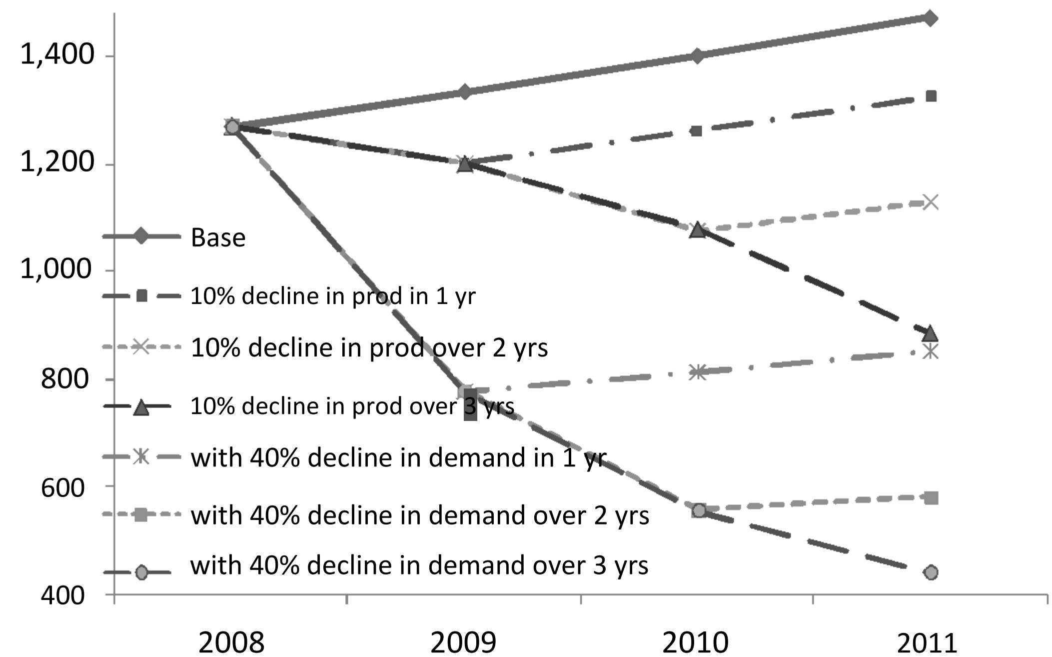

Figure 1. Chicken production under different scenarios (in base year prices, million cedis). Source: The Ghana DCGE model results.

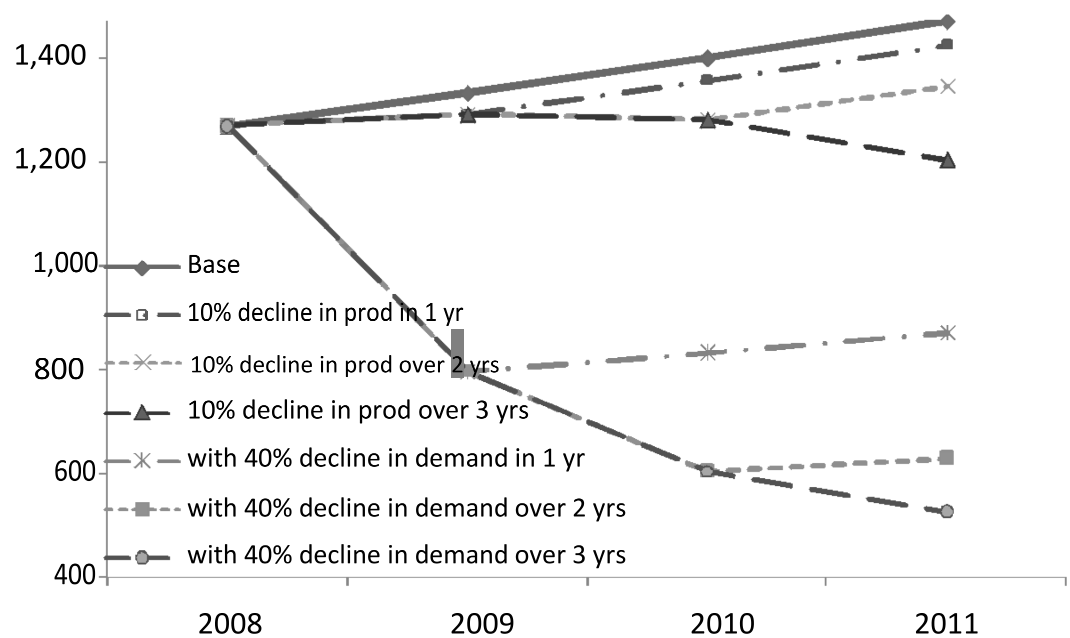

Figure 2. Chicken production revenue under different scenarios (in base year prices, million cedis). Source: The Ghana DCGE model results.

which demand for chicken remains low, the more serious the effect on maize and soybean production. The calculated average annual growth rate in the first part of Table 3 shows this. The three-year average annual growth rate between 2009 and 2011 is 3.8% for maize and 3.2 % for soybean, if chicken production declines by 10% in only one year, and such growth rates are lower than the base run's 4.1 and 5.1% for maize and soybean, respectively. However, in the worst-case scenario of an additional 40% decline in chicken demand over three years (Scenario 6), the annual growth rate for maize falls to 1.9% and becomes negative (-10.1%) for soybeans (Table 3, first part).

Table 3 also reports the economywide impact of HPAI

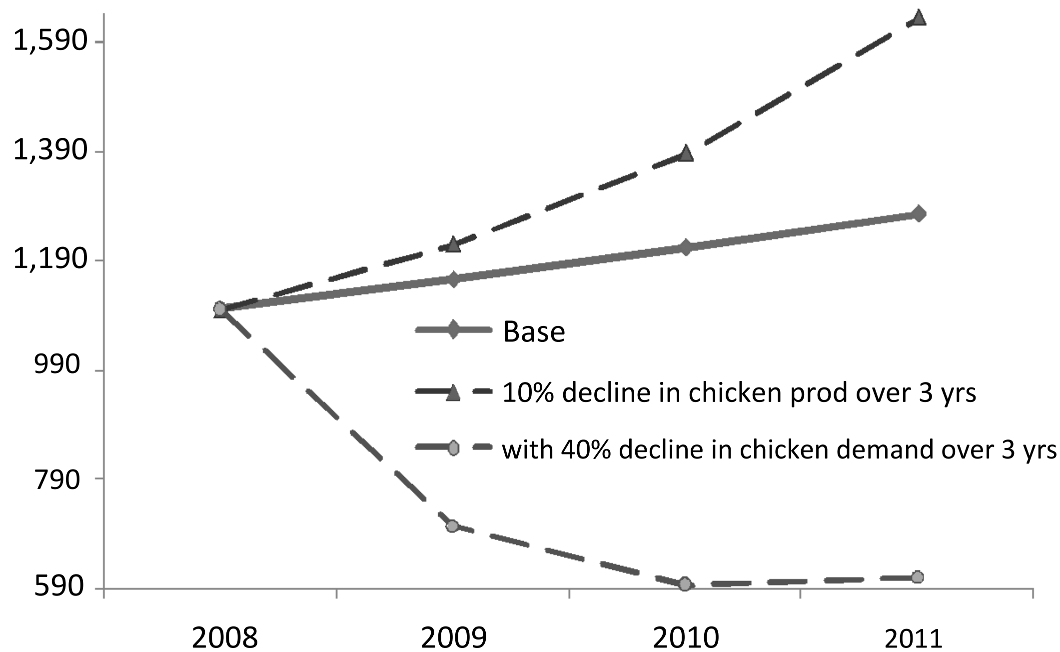

Figure 3. Chicken imports under different scenarios (in base year prices, million cedis). Source: The Ghana DCGE model results.

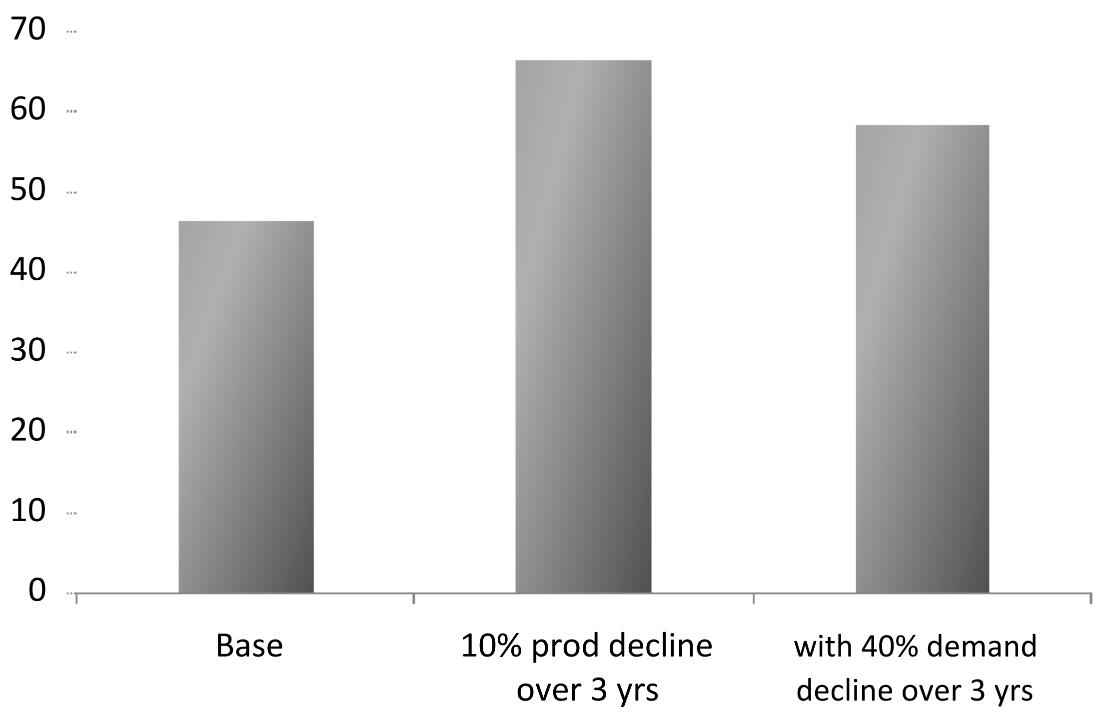

Figure 4. Share of chicken imports in total domestic consumption by 2011 under different scenarios (%).Source: The Ghana DCGE model results.

on the livestock subsector, AgGDP, and GDP. In the worst-case scenario, in which chicken production falls by70% in 2011 from the same year's level in the base run, total livestock production falls by 10.3%. However, in terms of AgGDP, the decline is only 0.4%, while there seems to be no effect on national total GDP (the last column of the second part of Table 3). The small effect on the aggregate agricultural sector and overall economy

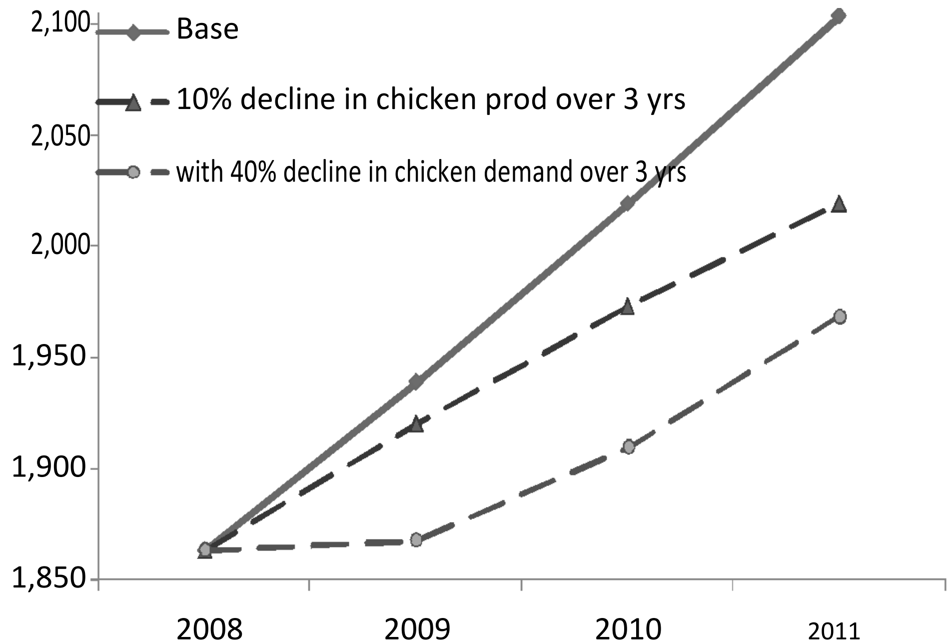

Figure 5. Indirect impact of HPAI on maize production under different scenarios (in base year prices, million cedis). Source: The Ghana DCGE model results.

is due not only to the small share of chicken in the economy (only 1.1% of AgGDP and 0.6% of GDP); it is also due to certain substitution effects in both production and consumption. When consumers must reduce their chicken consumption because of their income, they will consume more of other food products. Such demand substitution, though very small, can benefit producers who produce food products other than maize and soybeans.

Measuring income effects of HPAI outbreak on the poor

Steady economic growth has helped Ghana significantly reduce poverty in the last 20 years. Ghana's national poverty rate has fallen from 51.7% in 1991/92 and 39.5% in 1998/99 to 28.5% in 2005/06. While more poverty reduction has been achieved in rural areas in recent years, the rural population still accounts for most of the national poor, with a poverty rate of 39.2% in 2005/06. Thus, it is necessary to assess whether HPAI affects the rural poor more than the urban poor. The DCGE model includes 40 representative rural household groups, 12 of which represent rural households with incomes below the national poverty rate. We focus on these households for the income effect analysis. To reduce the size of a table or figure we aggregate their income together according to the main sources: labor, capital, and land.

As shown in the first column of Table 4, land is the most important income source for poor rural households, accounting for more than 55%, as agricultural crop production is the main activity they are involved in. The poor obtain 37.5% of their income from labor, including family labor working on their own land, and employment in both farm (hired by other farmers) and nonfarm activities. Income from capital, including capital used in chicken production, accounts for only 7.2% of income for poor households. With such an income structure, a 10% decline in chicken production in one year (year 2009) results in a 0.02% decline in the total labor income of the poorest 30% of rural households that year, compared with the income level in the same year in the base run. With a similar income reduction in capital earning and no effect on land returns, the total income for poor rural households falls about 0.0%, given a 10% chicken production decline. When the 10% decline in chicken production lasts for a longer period, the negative effect on labor income increases, and the greatest decline is 0.22% in 2011, compared with the level in base-run 2011. However, returns to land start to increase, with more farmers switching from chicken production to crop production. Because of this, the negative effect on total income increases only modestly, to 0.06%.

The total effect of a consumer demand shock on income is quite different from the effect of a production shock only. As shown in Table 4 and Figure 6, while the negative effect on labor income becomes more serious the greater the decline in production due to demand shock in Scenario 4–Scenario 6, returns to other factors, particularly to land, start to rise. As a result, the total income of the poor rural household increases slightly

Variable	Base	Annual growth rate (2008 to 2011)					
		10% decline in chicken production in 2009	10% decline in chicken production in 2009 to 2010	10% decline in chicken production in 2009 to 2011	With 40% decline in chicken demand in 2009	With 40% decline in chicken demand in 2009 to 2010	With 40% decline in chicken demand in 2009 to 2011
Chicken	5.1	1.4	-3.8	-11.4	-12.4	-22.9	-29.7
Soybean	5.1	3.2	0.5	-3.0	-3.4	-7.7	-10.1
Maize	4.1	3.8	3.3	2.7	2.8	2.2	1.9
Livestock	4.8	4.3	3.5	2.5	2.7	1.7	1.1
AgGDP	4.3	4.3	4.2	4.2	4.2	4.2	4.1
GDP	5.1	5.1	5.1	5.1	5.1	5.1	5.1
		Difference from the base-run same year (%)					
		2009	2010	2011	2009	2010	2011
Chicken		-10.0	-23.1	-39.9	-41.6	-60.2	-70.0
Soybean		-5.4	-12.4	-21.5	-22.2	-32.1	-37.3
Maize		-1.0	-2.3	-4.0	-3.7	-5.4	-6.4
Livestock		-1.6	-3.8	-6.5	-6.0	-8.8	-10.3
AgGDP		-0.1	-0.1	-0.2	-0.3	-0.4	-0.4
GDP		0.0	-0.1	-0.1	0.0	0.0	0.0

Source: The Ghana DCGE model results.

Table 4. Income effects of HPAI on the poor under different scenarios (%).

Variable	Share in total income	% Difference from the base-run same year					
		10% decline in chicken production in 2009	10% decline in chicken production in 2009 to 2010	10% decline in chicken production in 2009 to 2011	With 40% decline in chicken demand in 2009	With 40% decline in chicken demand in 2009 to 2010	With 40% decline in chicken demand in 2009 to 2011
		2009	2010	2011	2009	2010	2011
Labor	37.5	-0.02	-0.08	-0.22	-0.10	-0.18	-0.29
Capital	7.2	-0.02	-0.04	-0.07	0.20	0.24	0.19
Land	55.3	0.00	0.02	0.05	0.31	0.42	0.43
Total	100	-0.01	-0.02	-0.06	0.15	0.18	0.14

Source: The Ghana DCGE model results. % change from the base-run same year, and incomes are deflated by the same year's consumer price index.

(between 0.14 and 0.18 %)) compared with the same year's income level in the base run. Increases in the returns to land are the result of substitution in food consumption, given that in most households (particularly those in urban areas that are not directly affected by the is actually allocated to spending on other food and nonfood products. Increased food demand causes crop production (other than maize and soybean), and hence the returns to land in total, to rise slightly. As for the poorest 30 %) of rural households, chicken consumption as a response to the HPAI shock. While rural households whose income depends on chicken production will be hurt directly, the DCGE model cannot distinguish such households from the others. The micro-level analysis using the household survey data will fill in this gap (Birol and Asare-Marfo, 2008).

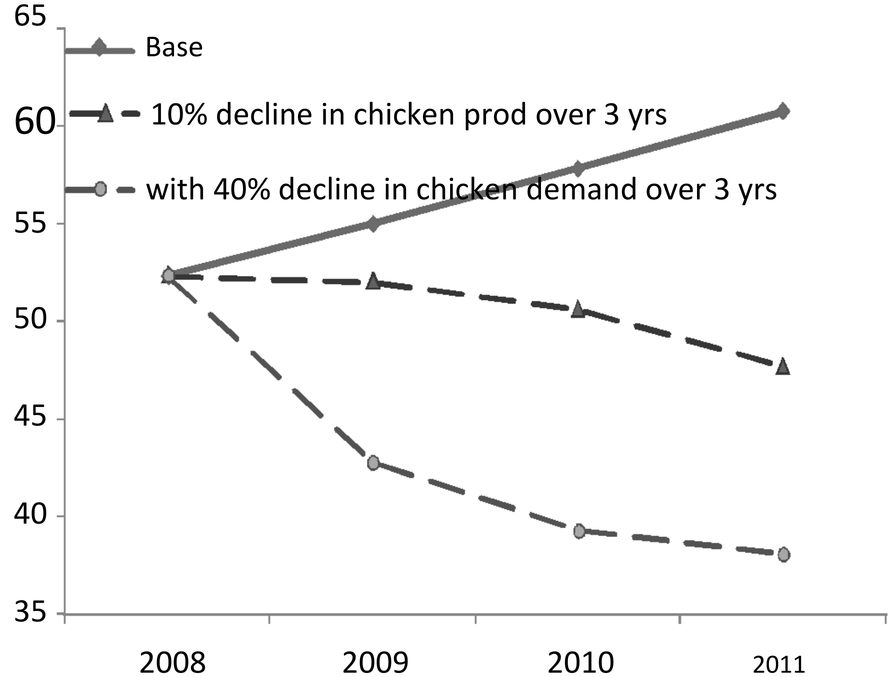

Figure 6. Indirect impact of HPAI on soybean production under different scenarios (in base year prices, million cedis). Source: The Ghana DCGE model results.

Conclusions

in Ghana under different scenarios. Given the very diverse Ghanaian diet and increased international competition in the domestic poultry market, chicken is a quite small sector of the Ghanaian economy, both as a share of AgGDP (1.1%) and of total agricultural production (2.3%). With this economic structure in mind, the DCGE model analysis shows that the shock in chicken demand due to consumers' anxieties is the dominant factor in causing chicken production to fall. A 40% reduction in chicken demand causes domestic production to fall more than 40%, with certain import substitutions. While imports also fall, the ratio of imports to total domestic consumption rises. Without a strong negative response to HPAI on the demand side, the domestic chicken price will rise with the shortage in supply. While a 40% decline in chicken demand will reverse this case, the model does not show any significant drop in the chicken price at the new equilibrium with a much lower level of demand and supply.

Soybean and maize are the two crop sectors that will be the most negatively affected by the decline in chicken production, as both are used as chicken feed. Under the worst-case scenario, soybean production will fall by 37% and maize by 6.4%, compared with the level in the same year of the base run. However, the economywide impact on both AgGDP and GDP is very small. In the worst-case scenario, in which chicken production falls by 70% in 2011 from the same year's level in the base run, AgGDP falls by only 0.4% and GDP is almost unchanged. This is not only because of the small poultry sector in the Ghanaian economy but because of certain substitution effects in both production and consumption. When consumers must reduce their chicken consumption, given their income, they will consume more of other food products. Such demand substitution, though very small, can benefit producers who produce food products other than maize and soybean.

About 40% of rural households have incomes below the national poverty line. The DCGE model is also used to assess the possible income effects of HPAI on the rural poor. Given that more than 50% of the income for poor rural households comes from crop production associated with returns to land, the negative income effect is quite small. Moreover, poor rural households as a group benefit from consumers switching away from chicken consumption to increased consumption of other foods. Demand for food crops results in an increase in the returns to land. While poor chicken farmers are definitely hurt directly by the reduction in chicken production, the DCGE model cannot distinguish them from other farmers. Micro-level analysis of chicken producers' livelihood, therefore, is necessary.

ACKNOWLEDGEMENTS

This study is part of Pro-poor HPAI Risk Reduction Strategies Research Project collaboratively implemented by International Food Policy Research Institute and International Livestock Research Institute and funded by the UK Department for International Development. Author has benefited from collaborative research with the project team members from both institutes and the participants of the second Steering Committee meetings of the project held in Sharm El Sheikh, Egypt on 27 October, 2008. The views expressed in this report are those of the author and are not necessarily endorsed by or representative of IFPRI or ILRI, or of the cosponsoring or supporting organizations. This report is intended for discussion.

REFERENCES

Aning KG, Turkson PK, Asuming-Brempong S (2008). Pro-poor HPAI risk reduction strategies in Ghana. Background paper. Africa/Indonesia Region Report No. 2. HPAI Project, IFPRI, http://www.hpai-research.net/index.html.

Birol E, Asare-Marfo D (2008). The impact of HPAI outbreaks on Ghanaian chicken producers' livelihoods. Memo, International Food Policy Research Institute.

Breisinger C, Diao X, Thurlow J (2009). Modeling growth options and structural change to reach middle income country status: The case of Ghana. Econ. Model., 26: 514–525.

Breisinger C, Diao X, Thurlow J, Al-Hassan R (2008). Agriculture for development in Ghana: New opportunities and challenges. Discussion Paper 784, International Food Policy Research Institute.

Breisinger C, Diao X, Thurlow J, Yu B, Kolavalli S (2008). Accelerating growth and structural transformation: Ghana's options for reaching middle-income country status. Discussion Paper 750, International Food Policy Research Institute.

Breisinger C, Thurlow v, Duncan M, eds. (2007). A 2005 social accounting matrix for Ghana. Accra, Ghana, and Washington, DC: Ghana Statistical Services and International Food Policy Research Institute. http://www.ifpri.org/data/ghana03.asp.

Diao X, Hazell P, Resnick D, Thurlow J (2007a). The role of agriculture in development: Implications for Sub-Saharan Africa. IFPRI Research Report No. 153. Washington, DC: International Food Policy Research Institute.

Diao X, Rattsø J, Stokke HE (2005). International spillovers, productivity growth and openness in Thailand: An intertemporal general equilibrium model analysis. J. Dev. Econ., 76(2005): 429–450.

Diao X, Yeldan E, Roe T (1998). A simple dynamic applied general equilibrium model of a small open economy: Transitional dynamics and trade policy. J. Econom. Dev., 23(1): 77–101.

Gohin A(2005). The specification of price and income elasticities in computable general equilibrium models: An application of latent separability. Econ. Model., 22: 905–925.

King RP, Byerlee D(1978). Factor intensities and locational linkages of rural consumption patterns in Sierra Leone. Am. J. Agric. Econ., 60(2): 197–206.

Lofgren H, Harris R, Robinson S (2001). "A Standard Computable General Equilibrium (DCGE) Model in GAMS." Trade and Macroeconomics Discussion Paper No. 75, International Food Policy Research Institute, Washington, D.C.

Thurlow J (2004). A Dynamic Computable General Equilibrium (DCGE) Model for South Africa: Extending the Static IFPRI Model." Trade and Industrial Policy Strategies, Johannesburg.

Vanzetti D (2007). Chicken supreme: How the Indonesian poultry sector can survive Avian influenza. Paper presented at the 51st AARES Annual Conference, Queenstown, New Zealand, February 13–16, 2007.

Yu W, Hertel T, Prechel PV, Eales JS (2003). Projecting world food demand using alternative demand systems. Econ. Model., 21: 99–129.

APPENDIX

Table A1. Economic structure of Ghana – Aggregate sectors.

Variable	Share in GDP	Share in total production	Share in total employment	Share in total exports	Share of exports in production	Share in total imports	Share of imports in consumption
Agriculture	35.1	27.1	22.3	43.1	28.9	7.5	10.6
Cereals	3.3	2.5	1.1	0.0	0.0	4.6	34.5
Root crops	8.7	6.6	3.2	0.3	0.9	0.0	0.0
Other staple crops	8.3	6.4	3.1	1.7	4.8	0.0	0.0
Export crops	6.5	4.9	2.7	26.6	99.1	0.2	5.3
Livestock	2.5	2.2	3.9	0.6	4.7	2.8	27.9
Fish and forestry	5.7	4.5	8.3	14.5	58.2	0.0	0.0
Industry	30.5	36.1	31.3	45.5	22.9	69.5	42.5
Mining	6.7	5.9	3.9	31.2	95.5	0.0	0.0
Manufacturing	10.0	18.1	12.1	14.3	14.3	69.4	55.3
Processing	6.4	9.1	8.5	13.9	27.8	18.0	44.0
Food processing	3.5	5.6	4.6	5.9	18.9	11.5	42.8
Other industry	13.8	12.0	15.3	0.0	0.0	0.1	0.3
Services	34.5	36.9	46.4	11.4	5.6	0.0	0.0
National economy	100.0	100.0	100.0	100.0	18.2	77.0	27.3

Source: Ghana Social Accounting Matrix (2005).

Table A2. Economic structure of Ghana – Agriculture.

Variable	Share in AgGDP	Share in agricultural production	Share in agricultural employment	Share in agricultural exports	Share of exports in production	Share in agricultural imports	Share of imports in consumption
Maize	6.1	5.7	3.1	0.0	0.0	11.5	15.3
Rice	2.2	2.5	1.3	0.0	0.0	49.6	55.4
Sorghum and millet	1.2	1.1	0.7	0.0	0.0	0.0	0.0
Cassava	10.8	10.5	5.9	0.0	0.0	0.0	0.0
Yams	11.4	11.3	6.7	0.8	2.0	0.0	0.0
Coco yams	2.6	2.7	1.7	0.0	0.0	0.0	0.0
Cowpea	1.1	1.0	0.7	0.0	0.0	0.0	0.0
Soybean	0.2	0.2	0.1	0.0	0.0	0.0	0.0
Palm oil	2.0	2.0	1.2	2.1	30.4	0.0	0.0
Groundnuts	1.8	1.8	1.4	0.5	8.3	0.0	0.0

Table A2. Contd.

Tree nuts	1.1	1.0	0.7	1.2	35.7	0.0	0.0
Fruit, domestic	2.0	1.7	1.2	0.0	0.0	0.0	0.0
Vegetable, domestic	11.0	9.5	5.9	0.0	0.0	0.0	0.0
Plantains	4.4	6.3	2.9	0.0	0.0	0.0	0.0
Fruit, export	0.8	0.7	0.5	2.0	82.2	0.0	0.0
Vegetable, export	0.2	0.3	0.1	0.8	79.9	0.0	0.0
Cocoa beans	16.8	16.1	11.0	57.5	103.4	0.0	0.0
Other crops	0.4	0.4	0.2	0.0	0.0	2.0	30.8
Export industrial crops	0.4	0.5	0.3	1.4	77.5	0.0	0.0
Chicken broiler	0.0	0.1	0.1	0.0	0.0	13.6	77.2
Eggs and layers	1.1	2.2	2.6	0.0	0.0	4.4	14.8
Beef	1.5	1.8	3.8	0.0	0.0	10.2	33.2
Sheep and goat meat	1.6	1.4	4.0	0.0	0.0	2.2	12.7
Other meats	2.7	2.6	6.9	0.0	0.0	6.5	18.4
Forestry	11.1	11.2	23.1	28.4	73.1	0.0	0.0
Fishing	5.2	5.5	13.9	5.2	27.5	0.0	0.0
Agriculture total	100.0	100.0	100.0	100.0	28.9	100.0	10.6

Source: Ghana Social Accounting Matrix (2005).

Table A3. Chicken production in agriculture by zones (%).

Variable	In each zone total agriculture	In national chicken	In national agriculture
Coast	7.7	36.4	10.9
Forest	2.2	39.0	41.4
S. Savanna	0.5	6.0	27.3
N. Savanna	2.1	18.5	20.4
National	2.3	100.0	100.0

Source: Ghana Social Accounting Matrix (2005).