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HPAI PRO-POOR HPAI RISK REDUCTION

Economywide Impact of Avian Flu in Ghana: A Dynamic CGE Model Analysis

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Preface

Since its re-emergence, HPAI H5N1 has attracted considerable public and media attention because the viruses involved have been shown to be capable of producing fatal disease in humans. While there is fear that the virus may mutate into a strain capable of sustained human-to-human transmission, the greatest impact to date has been on the highly diverse poultry industries in affected countries. In response to this, HPAI control measures have so far focused on implementing prevention and eradication measures in poultry populations, with more than 175 million birds culled in Southeast Asia alone.

Until now, significantly less emphasis has been placed on assessing the efficacy of risk reduction measures, including their effects on the livelihoods of smallholder farmers and their families. In order to improve local and global capacity for evidence-based decision making on the control of HPAI (and other diseases with epidemic potential), which inevitably has major social and economic impacts, the UK Department for International Development (DFID) has agreed to fund a collaborative, multidisciplinary HPAI research project for Southeast Asia and Africa.

The specific purpose of the project is to aid decision makers in developing evidence-based, pro-poor HPAI control measures at national and international levels. These control measures should not only be cost-effective and efficient in reducing disease risk, but also protect and enhance livelihoods, particularly those of smallholder producers in developing countries, who are and will remain the majority of livestock producers in these countries for some time to come.

To facilitate the development of evidence based pro-poor HPAI control measures the project is designed so that there are five work streams: disease risk, livelihood impact, institutional mechanisms, risk communication, and synthesis analysis. Project teams are allocating and collecting various types of data from study countries and employing novel methodologies from several disciplines within each of these work streams. So that efforts aren't duplicated and the outputs of one type of analysis feeds into another the methodologies in each work stream will be applied in a cohesive framework to gain complementarities between them based on uniformity of baselines and assumptions so that policy makers can have consistent policy recommendations.

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More information

For more information about the project please refer to www.hpai-research.net.

1. Introduction

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 sub-national levels is used as the dataset 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 percent of national GDP (Table 1). Within agriculture, root crops compose the largest sub-sector, accounting for almost one-fourth of agricultural GDP (AgGDP). The second largest agricultural sub-sector is staple crops other than cereals and root crops, which includes plantains, pulses and oilseed crops. This sub-sector accounts for 23.6 percent of AgGDP. Livestock, including poultry, cattle, sheep, goats and other livestock products (Table 2), actually is the smallest sub-sector in agriculture, after export crops, (18.7 percent), fishery and forestry (16.3 percent) and grain crops (9.5 percent), and accounts for 7.1 percent of AgGDP.

Table 1: Economic structure of Ghana – Aggregate sectors

	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

As shown in Table 2, poultry, including chicken broilers, layers and eggs, accounts for 1.1 percent of AgGDP and 2.3 percent of agricultural production, and less than one-third of the production of the livestock sub-sector. With a relatively low (20 percent) 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 percent of domestic demand (Table 2). On the other hand, domestic demand for eggs is mainly met by domestic supply. Thus, chicken industry in Ghana, particularly among commercial chicken farmers, is dominated by layers and egg production, which account for more than 95 percent of chicken production in the country.

Table 2: Economic structure of Ghana – Agriculture

	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
Maize	2.1	1.6	0.7	0.0	0.0	0.9	15.3
Rice	0.8	0.7	0.3	0.0	0.0	3.7	55.4
Sorghum & millet	0.4	0.3	0.2	0.0	0.0	0.0	0.0
Cassava	3.8	2.8	1.3	0.0	0.0	0.0	0.0
Yams	4.0	3.1	1.5	0.3	2.0	0.0	0.0
Coco yams	0.9	0.7	0.4	0.0	0.0	0.0	0.0
Cowpea	0.4	0.3	0.1	0.0	0.0	0.0	0.0
Soybean	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Palm oil	0.7	0.5	0.3	0.9	30.4	0.0	0.0
Groundnuts	0.6	0.5	0.3	0.2	8.3	0.0	0.0
Tree nuts	0.4	0.3	0.2	0.5	35.7	0.0	0.0
Fruit, domestic	0.7	0.5	0.3	0.0	0.0	0.0	0.0
Vegetable, domestic	3.9	2.6	1.3	0.0	0.0	0.0	0.0
Plantains	1.5	1.7	0.6	0.0	0.0	0.0	0.0
Fruit, export	0.3	0.2	0.1	0.9	82.2	0.0	0.0
Vegetable, export	0.1	0.1	0.0	0.4	79.9	0.0	0.0
Cocoa beans	5.9	4.4	2.5	24.8	103.4	0.0	0.0
Other crops	0.1	0.1	0.1	0.0	0.0	0.2	30.8
Export industrial crops	0.2	0.1	0.1	0.6	77.5	0.0	0.0
Chicken broiler	0.0	0.0	0.0	0.0	0.0	1.0	77.2
Eggs and layers	0.4	0.6	0.6	0.0	0.0	0.3	14.8
Beef	0.5	0.5	0.9	0.0	0.0	0.8	33.2
Sheep & goat meat	0.6	0.4	0.9	0.0	0.0	0.2	12.7
Other meats	1.0	0.7	1.5	0.0	0.0	0.5	18.4
Forestry	3.9	3.0	5.2	12.2	73.1	0.0	0.0
Fishing	1.8	1.5	3.1	2.2	27.5	0.0	0.0

Source: Ghana Social Accounting Matrix 2005

While chicken industry is a relatively small sector in the Ghanaian economy, its importance varies at the sub-national level. The SAM and hence the CGE model include agricultural production at zonal level and four zones, Coast, Forest, South Savanna and North Savannah, are included. As shown in Table 3, chicken production is relatively more important in the Coast zone, accounting for 7.7 percent of zonal level agricultural production. On the other hand, chicken accounts for only 0.5 percent of South Savannah agriculture and 2.1 percent of North Savanna agriculture. While share of chicken in agricultural production is the highest in Coast zone among the four zones, in terms of national total chicken production, the Forest zone is the most important, accounting for 39 percent of national chicken production (table 3). 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).

Table 3: Chicken production in agriculture by zones (%)

	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. Savannah	0.5	6.0	27.3
N. Savannah	2.1	18.5	20.4
National	2.3	100.0	100.0

Source: Ghana Social Accounting Matrix 2005

2. The Dynamic CGE Model, Recently Developed Ghana SAM, and the Model Scenarios

The Model

A general equilibrium model is the proper tool for analyzing any economywide impact of production, trade or demand shocks, as such a model captures the economic inter-linkages between agriculture and the rest of a country's economy. The dynamic general equilibrium (DCGE) model applied in this study is an extension of a static, standard CGE model that was developed in the early 2000s at IFPRI and has been documented in Lofgren (2000). The recursive dynamic version of the CGE model is based on this standard CGE model, with the incorporation of a series of dynamic factors. The early version of this dynamic CGE 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. 2008a) and agricultural development in Ghana in order to support the Comprehensive Africa Agriculture Development Program (CAADP) roundtable in Ghana (Breisinger et al. 2008b).

Similar to the other CGE models, our DCGE model is an economy-wide, multi-sectoral model that solves simultaneously and endogenously for a series of economic variables, including commodity and factor prices. However, unlike traditional CGE models that focus on national economies with multiple production sectors, our DCGE model considers sub-national heterogeneity in agricultural production by assigning a series of different production functions for producing a similar agricultural product, e.g., maize or poultry, to different regions. Such a model's setup requires more information about a country's agricultural production than a traditional CGE model: for instance, information about the distribution of land across regions for each individual 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 inter-linkages at both sub-national and national levels, including both the inter-linkages across regions and those between sectors.

Like any other CGE 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 sub-national level, or non-agricultural production that is defined at the national level. As in any other quantitative economic analysis, certain assumptions have to be applied before calibrating the model to the data. In a typical CGE 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 CGE 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 food processing industry, as well as for the relationship between intermediates and primary inputs in aggregation.

The demand side of the CGE model is dominated by a series of consumer demand functions. In our model, the system of consumer demand functions is solved from 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 budget.[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 process is the dominant income source for consumers, while incomes coming from abroad (as remittance received) or the government (as direct transfers) are also considered.

The relationship between supply and demand has to be explicitly modeled in a CGE model, and such a relationship determines the equilibrium prices in the domestic markets. Given that a CGE 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 CGE 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 the 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 export/import prices. Exports of this good fall and imports rise. On the other hand, if productivity improves in the domestic production and rising supply outpaces the increases in demand for the product, domestic price then falls relative to the border prices, 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

[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 percent of her (his) income on chicken consumption, indicating that the ABS for chicken is 2 percent. When this consumer's income increases in the next year, for each increased one dollar of income, she (he) prefers to spend 3 cents on chicken. In this case, the value of MBS for chicken is 3 percent. When MBS is greater than ABS for a particular consumption good (in this case, chicken), demand for this good is called income elastic. On the other hand, if MBS value is lower than ABS for a particular good, e.g., sorghum, demand for this good (sorghum) is said income inelastic.

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). On the other hand, growth in an export-oriented agricultural product, e.g. 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. To capture such a dynamic process is a key component of our DCGE model. Given the complexity of the model setup for Ghana, measured both in the large number of production sectors in agriculture and non-agriculture and in the disaggregated agricultural production and household groups across sub-national 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 the 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 sub-national and national level, and productivity growth are all exogenously determined.

The government is generally included in a CGE model as an institutional account. In our 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 as investments 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 of Rwanda can be found in the Appendix.

The 2005 Social Accounting Matrix for Ghana

The key dataset used in any CGE modeling analysis is called a social accounting matrix (SAM). The 2005 SAM of Ghana is constructed by Breisinger et al. (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. The SAM (and hence the model) also explicitly defines agricultural production at the four agro-ecological zonal levels. Broadly speaking, the Coastal Zone covers the Eastern and Volta regions; the Forest Zone includes Ashanti, Western and Central regions; the Southern Savannah comprises Brong Ahafo and part of Volta; and the Northern Zone includes the Upper West, Upper East and Northern regions. Because of this, there are 155 (28 x 4 + 33 + 10) production activities.

[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 4: Sectors/commodities in Ghana SAM and DCGE model

Agriculture	Industry	Services
Cereal crops	*Mining*	Trade services
Maize	Gold	Repairing, hotel, & restaurant
Rice	Other mining	Transport services
Sorghum & millet	*Food processing*	Communication
Other cereals	Formal food processing	Banking & business services
Root crops	Informal food processing	Real estate
Cassava	Cocoa processing	Community & other services
Yams	Sugar	Public administration
Coco yams	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 products?	
Livestock	Non-metallic mineral products	
Chicken broiler	Metal products	
Eggs and layers	Non-electrical machines	
Beef	Electrical machines	
Sheep & goat meat	Radio and television equipment	
Other meats	Medical and optical equipment	
Forestry	Motor vehicles	
Fishing	Motor vehicles parts	
	Other transport equipment	
	Other manufactured products	
	Other industry	
	Construction	
	Water	
	Electricity	

The demand side of the SAM and the model consists of 90 representative households 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 percent 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 non-agricultural activities, we assume that urban households earn incomes solely from non-agricultural 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 CGE model, well behaved structural functions that are solved from maximizing profits on the producer side and 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 sector and zonal level) play more important roles in determining the model results than elasticities do. All these parameters have to calibrate to the data, together with the predetermined elasticities.

Specifically, the substitution elasticity between primary inputs in the CES production function has to be assumed or chosen from the literature, as any country's dataset used to construct a CGE 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 CGE model, it then implicitly assumes a unit elasticity of substitution between primary inputs (e.g., labor, land and capital) in the production functions. In this way, other parameters in the CD production function of the model (e.g., the marginal product of each input, the key parameter in this type of function) can be directly calibrated using the country data of SAM (i.e., the share of value-added for each input employed in the total value-added of this sector). In our DCGE model, we chose a general CES function form (other than CD technology) to calibrate other parameters in the production function. The elasticity in the production function is pre-determined and drawn from CGE literature about other African countries. The other parameters in the production functions of the model are then calibrated using the data composed in the Ghana 2005 SAM. Also, we decided to use a 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, there are a set of fixed input-output coefficients applied in the production function and these coefficients are directly calibrated using the data of 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 Ghana SAM, to derive a series of MBSs the income elasticity of demand has to be obtained. For this study, the income elasticity is estimated from a semi-log inverse function suggested by King and Byerlee (1978) and based the data of 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 one. While we only estimate the income elasticity for rural and urban households as two groups, because of different budget shares spent on the same product (e.g., chicken) across 90 household groups, the marginal budget shares and hence price elasticities can be different across household groups. As in other CGE models, income and price elasticities are not directly used in the demand system, which composes a series of structural functions in the model.[4]

Limitations of the CGE Model

Like any other economic model, the CGE model has its limitations. Of these, 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. Marginal budget shares, 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 AIDADS demand system (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, similar to most other CGE 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 non-traditional and import-substitutable agriculture and of new manufacturing activities during a rapid growth period. To address some of these caveats, we run several sensitivity tests, whose results are reported in the Appendix.

[4] The implicit price elasticities can be derived from the structural demand functions used in the CGE 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 mathematic process to derive these price elasticities using the parameters and variables included in the CGE model can be obtained upon request from the author.

Bearing these caveats in mind, the CGE 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 Ghana SAM discussed above, the DCGE model is ready to conduct simulation analysis. We first discuss the simulations that we plan to do using this model.

The Model Scenarios

Three HPAI outbreaks had been reported in Ghana in April – June 2007 in various locations across the 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 AI affected chicken. Following Vanzetti (2007), we assume that an outbreak will directly lower chicken production by 10 percent 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 percent in 2009 from the same year's level in the base-run, and then the production comes back 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 come back in 2011, while in the third scenario we consider that the production will stay at its 2009 level until 2011. Scenarios 4 – 6 are designed for the demand shocks. In Scenario 4, in addition to the assumptions used in Scenario 1, the marginal budget share for chicken in the demand function is lowered in 2009 such that national chicken consumption is reduced by 40 percent compared with 2009's base-run. Similarly, Scenario 5 is for additional demand shock from Scenario 2 and Scenario 6 is for the same from Scenario 3. Table 5 summarizes these six scenarios, their assumptions and targeted direct effects. In reality, consumers' response to HPAI seems to become diminished with time. For example, instead of the same 40 percent decline in demand, we can assume a decline of 30 or 20 percent. 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.

Table 5: Summary of the CGE model scenarios

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

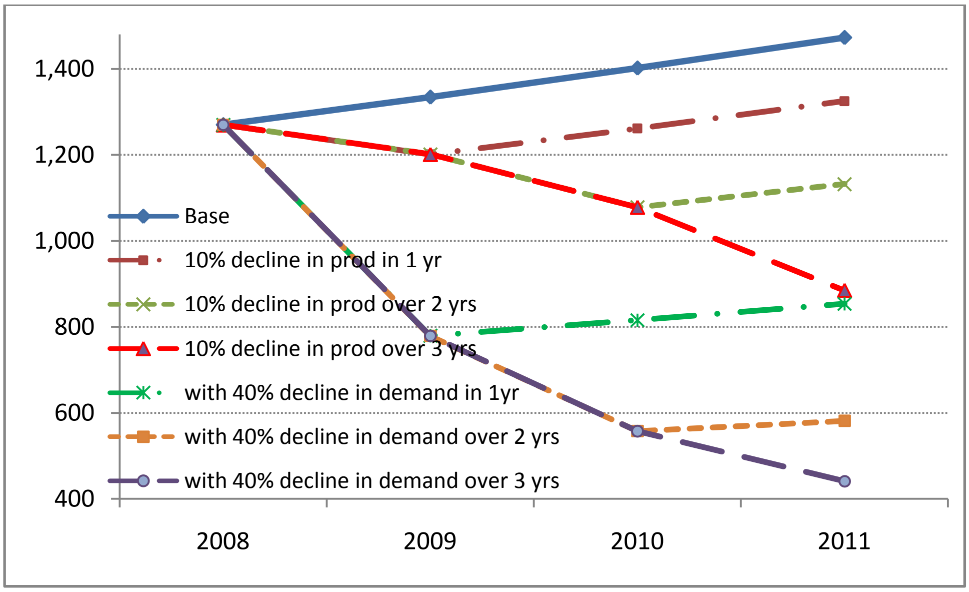
3. Discussion of the CGE Model Results

Demand Shocks Dominate the Impact on Chicken Production and Imports

Under all the six scenarios, the direct effect is always on the 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 percent in 2009, chicken production falls slightly more than 40 percent (at 41.6 percent). 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.

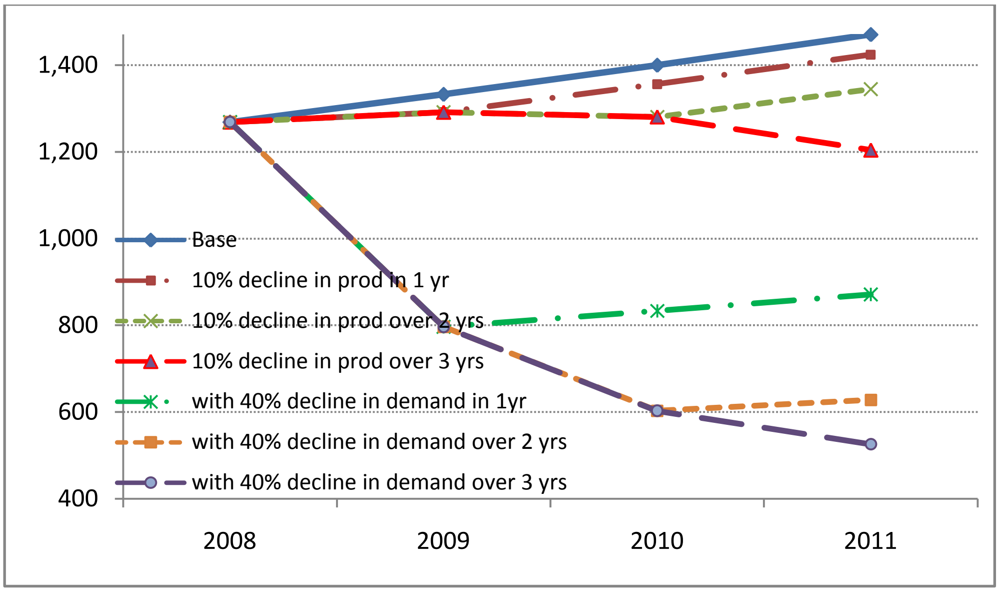
Comparing figures 1 and 2, we can see relatively larger differences between production and revenue effects when demand shock is ignored. With reduced production and without demand shock, prices rise with shortage in supply, which result in less reduction in chicken production revenue (in figure 2) than in production (figure 1). However, when demand shock is imposed in Scenarios 4 – 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 – 6, because both demand and production fall at a similar speed. 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.

Figure 1: Chicken production under different scenarios (in base year prices, million Cedis)



Source: The Ghana CGE model results

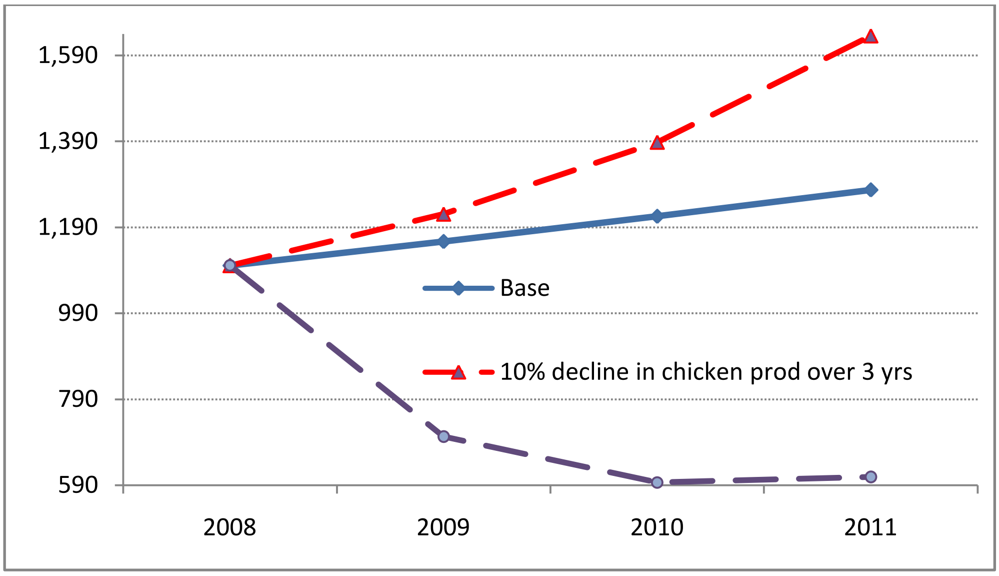
Figure 2: Chicken production revenue under different scenarios (in base year prices, million Cedis)



Source: The Ghana CGE model results

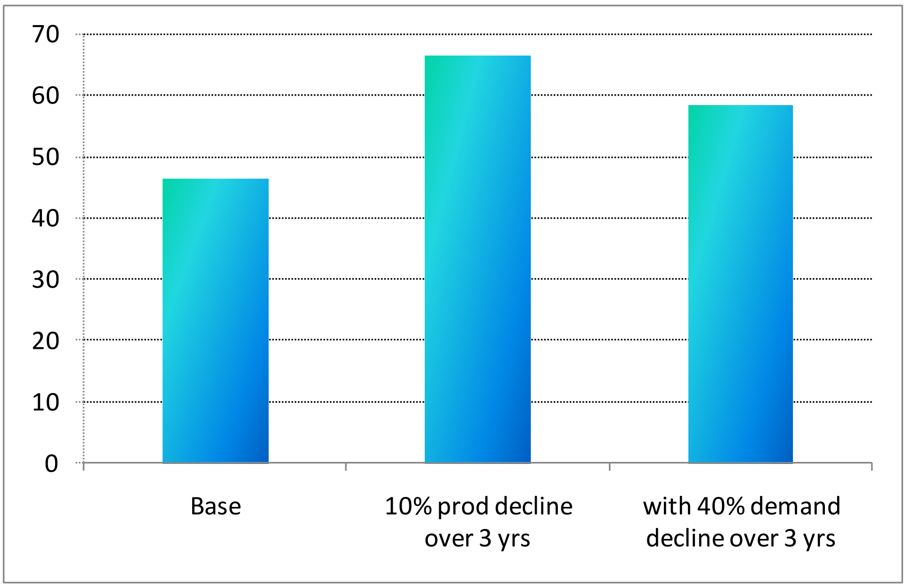
As we mentioned before, about 50 percent of the chicken consumed in the domestic market in Ghana is supplied through imports. While an HPAI outbreak occurs only among the domestic chicken production, demand for all kinds of chicken, whether imported or domestically produced, would fall due to consumers' 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 percent between 2009 and 2011 from the same year's level in the base-run, and Scenario 6, in which, additional 40 percent decline in chicken demand occurs in 2009-2011.

Figure 3: Chicken imports under different scenarios (in base year prices, million Cedis)



Source: The Ghana CGE model results

Figure 4: Share of chicken imports in total domestic consumption by 2011 under different scenarios (%)



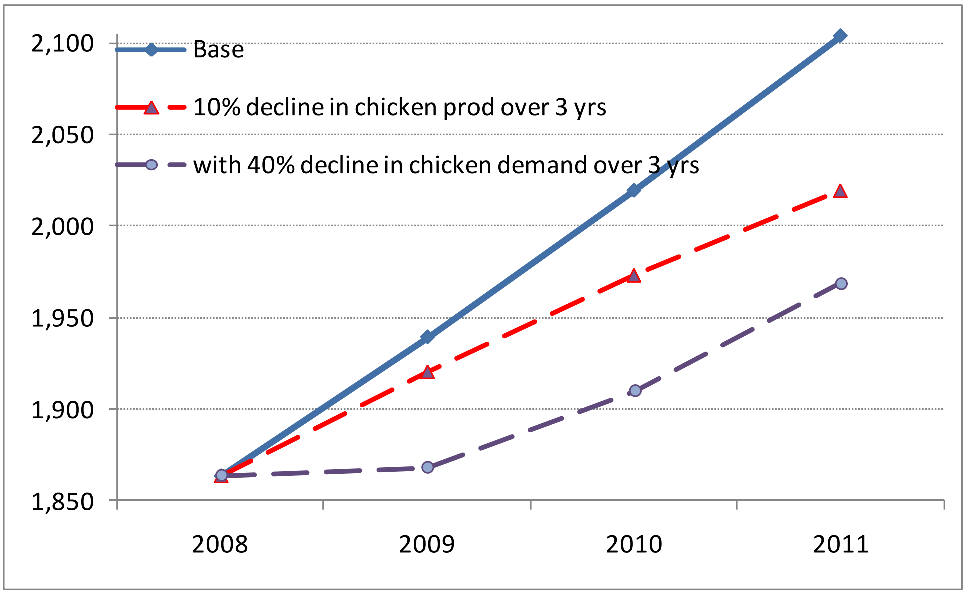
Source: The Ghana CGE model results

As shown in Figure 3, without 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 result in the ratio of imports to total consumption to rise (Figure 4). As shown in figure 4, with a 10 percent 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 of 0.46—all reported in the model for the year 2011. However, when consumers start to respond and lower their demand by 40 percent, 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

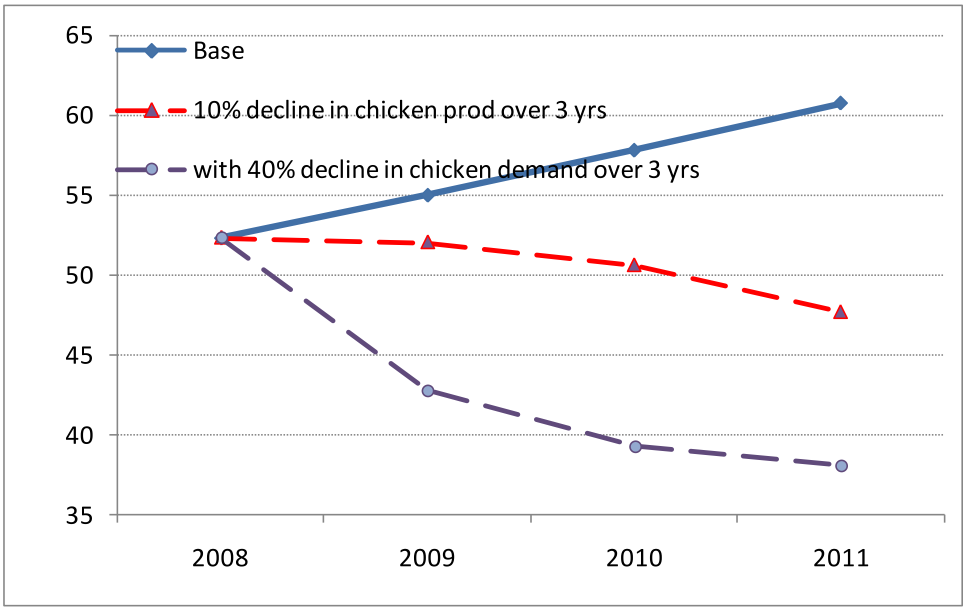
The main purpose of applying the CGE model in this study is to assess the indirect effect of HPAI outbreak, through the linkages of the chicken sector with the rest of the economy. Chicken production, particularly commercial chicken farms, employs maize as feed, combined with soybeans and other protein 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 CGE 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 percent, then maize and soybean production would fall by 1.0 and 5.4 percent, respectively (table 6, column one of the second part). When chicken production declines by 41.6 percent as a result of 40 percent reduction of chicken demand, maize and soybean production falls by 3.7 and 22.2 percent, respectively (table 6, column four of the second part). The longer the period in which demand for chicken stays low, the more serious of the effect on maize and soybean production. The calculated average annual growth rate in the first part of table 6 shows this. The three-year average annual growth rate between 2009 and 2011 is 3.8 percent for maize and 3.2 percent for soybean, if chicken production declines by 10 percent in only one year, and such growth rates are lower than the base-run's 4.1 and 5.1 percent for maize and soybean, respectively. However, in the worst case scenario of an additional 40 percent decline in chicken demand over three years (Scenario 6), the annual growth rate for maize falls to 1.9 percent and becomes negative (-10.1 percent) for soybeans (table 6, first part).

Figure 5: Indirect impact of HPAI on maize production under different scenarios (in base year prices, million Cedis)



Source: The Ghana CGE model results

Figure 6: Indirect impact of HPAI on soybean production under different scenarios (in base year prices, million Cedis)



Source: The Ghana CGE model results

Table 6 also reports the economywide impact of HPAI on the livestock sub-sector, AgGDP and GDP. In the worst case scenario in which chicken production falls by 70 percent in 2011 from the same year's level in the base-run, the total livestock production falls by 37.3 percent. However, in terms of agricultural GDP, the decline is only -0.4 percent, while there seems to be no effect on national total GDP (the last column of second part in table 6). The small effect on the aggregate agricultural sector and overall economy is not only due to the small share of chicken in the economy, which accounts for only 1.1 percent of AgGDP and 0.6 percent of GDP. It is also due to certain substitution effects in both production and consumption. When consumers have to 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.

Table 6: Growth effects of HPAI under different scenarios (%)

	Base	10% decline in chicken production in 2009	10% decline in chicken production in 2009-10	10% decline in chicken production in 2009-11	With 40% decline in chicken demand in 2009	With 40% decline in chicken demand in 2009-10	With 40% decline in chicken demand in 2009-11
Annual growth rate (2008-2011)							
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 CGE model results

Measuring Income Effects of HPAI Outbreak on the Poor

Steady economic growth has helped Ghana significantly reduce poverty in the last twenty years. Ghana's national poverty rate has fallen from 51.7 percent in 1991/92 and 39.5 percent in 1998/99 to 28.5 percent 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 percent in 2005/06. Thus, it is necessary to assess whether HPAI affects the rural poor more than the urban poor. The CGE 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.

Table 7: Income effects of HPAI on the poor under different scenarios (%)
(% change from the base-run same year, and incomes are deflated by the same year's CPI)

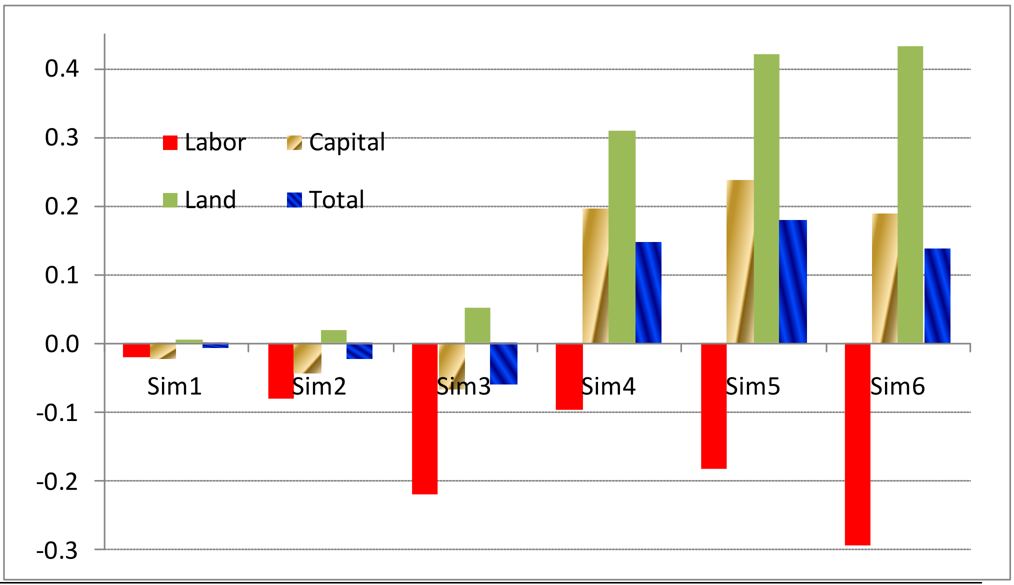
		% difference from the base-run's same year					
	Share in total income	**10% decline in chicken production in 2009**	**10% decline in chicken production in 2009-10**	**10% decline in chicken production in 2009-11**	**With 40% decline in chicken demand in 2009**	**With 40% decline in chicken demand in 2009-10**	**With 40% decline in chicken demand in 2009-11**
		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 CGE model results

As shown in the first column of table 7, land is the most important income source for the poor rural households, accounting for more than 55 percent, as agricultural crop production is the main activity they are involved in. 37.5 percent of their income comes from labor, including family labor working on their own land, and employment in both farm (hired by other farmers) and non-farm activities. Income from capital, including capital used in chicken production, accounts for only 7.2 percent of income for the poor households. With such an income structure, a 10 percent decline in chicken production in one year (year 2009) results in a 0.02 percent decline in the total labor income of the poorest 30 percent of rural households this 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 the poor rural households falls about 0.01 percent, given a 10 percent chicken production decline. When the 10 percent decline in chicken production lasts for a longer period, the negative effect on labor income increases and the greatest decline is -0.22 percent in 2011, compared with the level in base-run's 2011. On the other hand, 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 only increases modestly to -0.06 percent.

Figure 7: Income effect of HPAI on the poorest 30% of rural households under different scenarios

(% change from the base-run same year, and incomes are deflated by the same year's CPI)



Label	Scenarios	Year reported in figure
Sim1	10% decline in chicken production in 2009	2009
Sim2	10% decline in chicken production in 2009-10	2010
Sim3	10% decline in chicken production in 2009-11	2011
Sim4	With 40% decline in chicken demand in 2009	2009
Sim5	With 40% decline in chicken demand in 2009-10	2010
Sim6	With 40% decline in chicken demand in 2009-11	2011

Source: The Ghana CGE model results

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 7 and figure 7, while the negative effect on labor income becomes more serious the greater the decline in production due to demand shock in Sim4 – Sim6, returns to other factors, particularly to land start to rise. As a result the total income of the poor rural household increases slightly (between 0.14 and 0.18 percent) 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 the urban areas that are not directly affected by the chicken production shock), reduced spending on chicken is actually allocated to spending on other food and non-food 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 percent of rural households, given that more than 50 percent of their income is associated with crop production as returns to land, the poor rural households as a group actually benefit from declines in chicken consumption as a response to the HPAI shock. While the rural households whose income depends on chicken production will be hurt directly, the CGE model cannot distinguish such households from the others. The micro-level analysis using the household survey data will fill in this gap (see Birol and Asare-Marfo, 2008).

4. Conclusions

In this paper we developed a dynamic CGE model to quantitatively assess the economywide impact of HPAI 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 agricultural GDP (1.1 percent) and of total agricultural production (2.3 percent). With this economic structure in mind, the CGE 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 percent of reduction in chicken demand causes domestic production to fall more than 40 percent, 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, domestic chicken price would rise with the shortage in supply. While a 40-percent decline in chicken demand will reverse this case, the model does not show any significant drop in 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 percent and maize by 6.4 percent, compared with to level in the same year of 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 percent in 2011 from the same year's level in the base-run, AgGDP falls only by 0.4 percent and GDP is almost unchanged. This is not only because of a modest small poultry sector in the Ghanaian economy, but also due to certain substitution effects in both production and consumption. When consumers have to 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 percent of rural households have incomes below the national poverty line. The CGE model is also used to assess the possible income effects of HPAI on the rural poor. Given that more than 50 percent 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 definitely get hurt directly by the reduction in chicken production, the CGE model cannot distinguish them from the other farmers. Micro-level analysis of chicken producers' livelihood, therefore, is necessary.

5. References

Aning, K.G., P.K. Turkson, and S. Asuming-Brempong. 2008. Pro-Poor HPAI Risk Reduction Strategies in Ghana—Background Paper. Africa/Indonesia Region Report No. 2. http://www.hpairesearch.net/ index.html

Birol, E., and D. Asare-Marfo. 2008. The impact of HPAI outbreaks on Ghanaian chicken producers' livelihoods. A memo, IFPRI.

Breisinger, C., X. Diao, J. Thurlow, B. Yu, and S. Kolavalli. 2008a. Accelerating growth and structural transformation: Ghana's options for reaching middle-income country status, IFPRI Discussion Paper 750

Breisinger, C., X. Diao, J. Thurlow, and R. Al-Hassan. 2008b. Agriculture for development in Ghana: New opportunities and challenges, IFPRI Discussion Paper 784

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

Diao, X., E. Yeldan, and T. Roe. 1998. A dimple dynamic applied general equilibrium model of a small open economy: transitional dynamics and trade policy. *Journal of Economic Development* 23(1): 77-101

Diao, X., J. Rattsø, and H.E. Stokke. 2005. International Spillovers, Productivity Growth and Openness in Thailand: An Intertemporal General Equilibrium Model Analysis. *Journal of Development Economics* 76 (2005): 429-450

Gohin, A. 2005. The specification of price and income elasticities in computable general equilibrium models: an application of latent separability. *Economic Modeling* 22: 905-925.

Vanzetti, D. 2007. Chicken supreme: How the Indonesian poultry sector can survive avian influenza? Contributed paper at the 51st AARES Annual Conference, Queenstown, New Zealand, 13-16 February 2007.

Yu, W., Hertel, T., Prechel P.V., Eales, J.S. 2003. Projecting world food demand using alternative demand systems. *Economic Modeling* 21: 99-129.