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A Chicken and Maize Situation

The Poultry Feed Sector in Ghana

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ABSTRACT

As developing countries undergo agricultural transformation, the interactions between crop and livestock value chains will become increasingly important as drivers of growth. What is the nature and extent of these interactions, and how can policies foster growth in the value chains? This paper addresses these questions by researching two interlinked value chains in Ghana. The first, maize, is the country's most important cereal crop and is cultivated around the country. It serves as the main input for the production of the second value chain, poultry, a rapidly growing source of protein for Ghana's growing urban population. Policies and programs have sought to improve the productivity of these two sectors, and development policy discussions often dwell on the subject of the poultry sector's competitiveness against frozen meat imports.

This study focuses on the feed milling industry, which serves as the link between maize and poultry, through a field assessment of feed millers in Ghana. The findings establish the importance of feed in the poultry value chain. In addition, they show how the sector has become more integrated with poultry production, especially on larger-scale poultry farms. Because maize accounts for 60 percent of poultry feed, its availability and price have important implications for the profitability and growth potential of feed and, therefore, for poultry production as well. We illustrate these linkages by means of a simple spatial market equilibrium model that ties together the three sectors of the poultry value chain: the primary inputs (maize and soybeans), intermediate inputs (feed), and final products (meat and eggs). This model also enables us to assess the future growth potential of the poultry industry given alternative policy-driven changes in productivity and the production capacities of all three sectors. The results show that for poultry meat, replacing imports with domestic production in the short term would be nearly impossible. For the egg industry, however, there is potential for Ghana to export to neighboring countries by reducing production costs through improvements in yellow maize production.

Keywords: poultry; maize; feed mill; value chain; spatial market model; Ghana

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1. INTRODUCTION

In economic policy debates in Ghana, the condition of the local poultry industry is frequently used as a gauge for agricultural and economic development. Since the 1960s, successive Ghanaian governments have promoted poultry production as a means of improving food security, generating jobs, and diversifying sources of farm household incomes. Ghana has seen significant increases in poultry meat consumption. Driven by income growth and food preferences among the rapidly urbanizing population over the past decade, this consumption is expected to continue. The recent rise in the import bill, due in part to high levels of imports of frozen chicken meat, has brought renewed attention to the industry.[1] By most accounts, domestic poultry production in Ghana now accounts for less than 10 percent of the country's poultry meat consumption (USDA 2013). Killebrew and Plotnick (2010), citing Eurostat data, estimate that imports of frozen chicken from the EU alone increased by as much as 476 percent over 10 years (2000–2010). Ghana is the third-highest chicken meat importer in Africa south of the Sahara, after South Africa and Angola (UN 2013).

With the lack of competitiveness in the domestic sector and the perceived decline in domestic poultry production levels generally attributed to the rapid increase in imports of chicken meat, farmers have called for policy interventions to support domestic production by curtailing imports (Chisenga, Etsua-Mensah, and Sam 2007; Sumberg et al. 2013; FAO 2014). Accordingly, the government has implemented such policies, albeit in fits and starts. Policies to support domestic production have included both trade measures such as tariffs on imported chicken meat, and nontrade measures such as direct input supply for smallholder poultry farmers. These efforts have not been sustained, nor have they resulted in the expected decline of imports and rise of a competitive domestic poultry sector.

In addition to increasing farmer incomes and generating jobs within the sector, improving domestic poultry production could serve another purpose—spurring increased demand for maize and other ingredients used in poultry feed, and thereby benefiting smallholder farmers producing maize. Poultry feed forms a large chunk of the overall cost of poultry production; for both broiler and egg production, feed constitutes about 70 percent to 75 percent of production costs (FAO 2003; Davis et al. 2013; Ravindran 2013). The low cost of poultry production in countries such as Brazil and the United States is tied to the low cost of maize (and, hence, feed) in those countries (Davis et al. 2013). Thus, it is natural that Ghanaian policy makers would be anxious to boost maize production and in so doing reduce feed and overall production costs faced by poultry farmers. For example, in India, the availability of low-cost, high-quality maize for feed has ensured that domestic poultry production remains competitive against imports (Hellin et al. 2015).

Policy makers seeking to intervene in Ghana's poultry sector face a dearth of policy-relevant research to guide their decision process. Unfortunately, reliable, up-to-date information on trends in domestic poultry production is hard to find (Sumberg et al. 2013). Existing research consists mostly of assessments of production levels (Killebrew and Plotnick 2010; USDA 2013; FAO 2014), and qualitative assessments of the impacts of avian flu on production (Birol and Asare-Marfo 2008; Diao, 2008; Mensah-Bonsu and Rich, 2010). Although policy makers recognize the importance of maize in feed composition, there are no empirical studies of the linkage between Ghana's maize and poultry sectors, or the likely impacts of policies on production levels. The link between poultry and maize sectors at the global level is acknowledged (Shiferaw, Prasanna, and Bänziger 2011). However, it is an under-researched topic, with

[1]The high level of attention given to the poultry sector can be illustrated with a few examples. The first is President Mahama's speech to the UN General Assembly on September 21, 2016, in which he stated, "Some of the young Africans who hazard the desert and Mediterranean Sea to cross to Europe from my country are young poultry farmers …who sell their shops and undertake the journey because they can no longer compete with the tons of frozen chicken dumped on African markets …" (http://myjoyonline.com/Mahama-address-UN.pdf). Another example is the State of the Nation addresses in 2014 and 2015, in which he pledged government support for domestic poultry production (http://www.myjoyonline.com/news/2014/February-26th/full-transcript-president-john-mahamas-2014-state-of-the-nation-address.php; https://www.ghanabusinessnews.com/2015/02/28/structure-of-the-economy-to-be-changed-mahama./). Finally, project interventions to support poultry production have been promoted by the government and donors such as the U.S. Department of Agriculture.

the exception of some analyses of the contribution of maize to the success of poultry production in India (Hellin, Erenstein, and Pixley 2010, 2015).

There is an acute lack of reliable information on poultry production in Ghana to aid evidence-based policy decisions. Both the government and industry sources seem to be agreed on one point: domestic poultry production has reduced drastically in the face of intense competition from imported frozen chicken, and government support is needed to revive and ensure the survival of this industry. Several questions need to be addressed in considering policy options. First, is it realistic to expect domestic production to displace imports through expanded production or even the use of tariffs to discourage imports? Where and how should public support for the poultry industry be delivered—should it be targeted primarily at reducing the costs of inputs such as feed and day-old chicks (DOCs), improving farm production technology, or upgrading processing facilities? What is the relative importance of feed costs compared with losses due to improper farm practices, cost and quality of DOCs, and the cost and supply of vaccines and drugs? If policies were to focus on the feed-poultry linkage, to what extent would an increase in domestic poultry production expand the market for domestic maize? The answers to these questions require detailed information on maize production, the feed sector, and poultry production.

This paper reports on a study of the linkage between maize, feed production, and poultry production in Ghana. The research combines a detailed analysis of the feed sector and reviews the available data on maize and poultry production. The study provides information on Ghana's poultry sector that should be of interest to policy makers, and it also represents an uncommon approach of linking crop and livestock value chains. The central policy questions guiding this study are whether improvements in domestic maize productivity and production levels can drive growth in domestic poultry production and, in turn, whether boosting domestic poultry production can serve as a demand pull for domestically produced maize. For both questions, we analyze the role of policy shocks in price comparisons between locally produced and imported products (chicken meat and maize) to predict whether the policies can achieve their expected goals.

The research aims to understand the linkages between the two sectors. It uses the feed sector as a guide, since demand for feed is derived from the poultry sector. Although Ghana's poultry sector is diverse and dominated mainly by small-scale backyard producers, we focus on commercial producers, which account for most of the poultry products on the market. This is because backyard producers feed their birds through scavenging and do not necessarily use high-quality feed produced from maize and other standardized ingredients. Therefore, the linkage between the maize and poultry sectors is observed primarily through feed production among commercial poultry farmers.

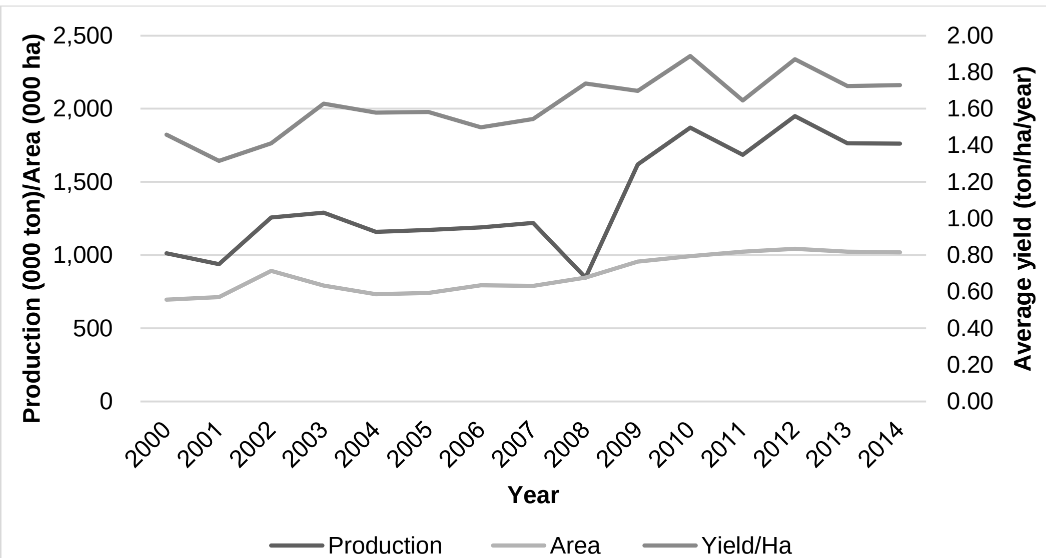
The analysis is based on a field assessment of the feed sector combined. It uses a spatial market model that links feed and maize production on the backward channel of the value chain, and commercial poultry production on the forward channel. The field assessment is based on interviews conducted in the poultry-feed-producing areas of Ghana in August 2015 and from May through July 2016. The spatial market model is based on the findings of interviews, as well as available data from reliable sources. It examines how changes in one sector (whether as improvements or variations in the output of the maize, feed, or poultry sectors) affect equilibrium prices within each sector and, in the process, the extent to which imports are displaced by domestic supply. The study explicitly accounts for the geographic location of production and demand within each of the three sectors in determining market equilibrium prices and quantities, as well as trade flows, among locations.

The next two sections briefly describe the maize and poultry sectors in Ghana. The fourth section examines the methodology and findings from the field assessments of the feed industry in Ghana. A fifth section describes the methodology and results of the spatial market model. The paper concludes with a summary of the main findings and some policy implications.

2. MAIZE PRODUCTION IN GHANA

Maize is Ghana's most important cereal crop and is grown by the vast majority of rural households. It is widely consumed throughout the country and is the second most important staple food in Ghana, next to cassava. Maize is the main input in feed production for poultry. Production in Ghana averaged 1.8 million metric tons per year harvested from about 1.02 million hectares over the last five years (2010 to 2014). Both production of and area cultivated for maize have increased over time (Figure 2.1). Production has risen slightly faster than area and, therefore, yield (in ton/ha) has increased slightly (Figure 2.1). The national average yield was 1.73 tons/ha/year in 2014, and there is a great opportunity to further increase yield to reach the achievable levels of 4 tons/ha to 6 tons/ha based on on-station and on-farm trials. The annual growth of yields has remained low. Nevertheless, it has averaged about 1.5 percent per year since 2000, clearly implying the potential to grow faster given a large yield gap.

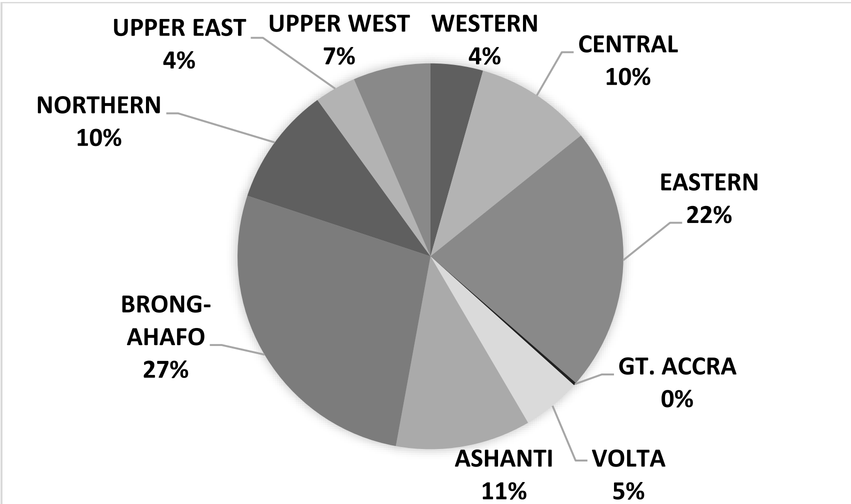
Figure 2.1 Maize production, area cultivated, and yield per hectare, 2000–2014



Source: Raw data from Statistics, Research, and Information Directorate, Ministry of Food and Agriculture (2015).

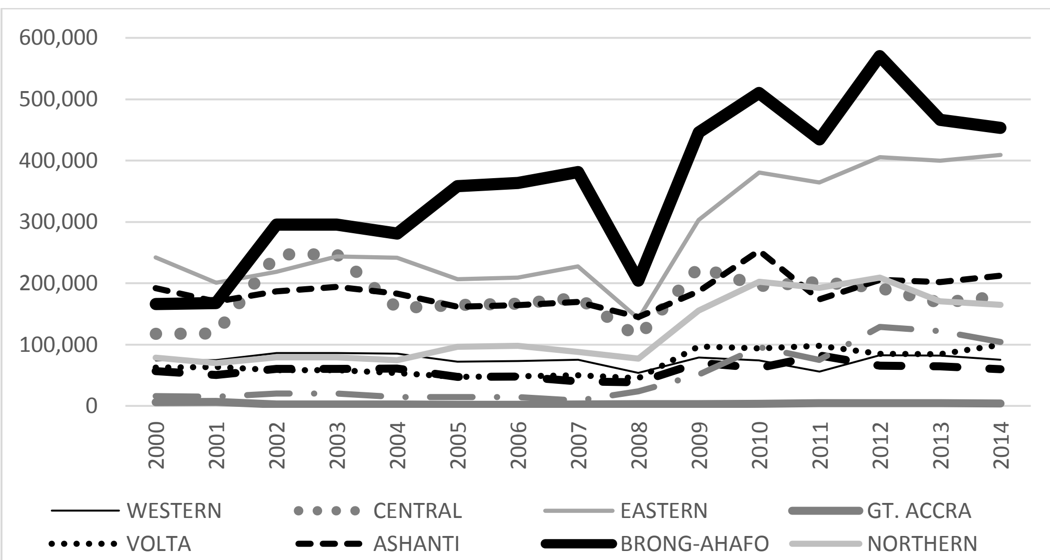
Maize is grown in all regions. Production remains highest in Brong Ahafo, which accounts for 27 percent of national production—the average from 2012 to 2014 (Figure 2.2). The Eastern Region comes close, contributing 22 percent of national production. Both regions have also increased maize production over time (Figure 2.3). Combined with Ashanti, these three regions—known as the middle maize belt of Ghana—account for 60 percent of national maize production. The Northern, Central, and Upper West regions also produce maize, contributing 10 percent, 10 percent, and 7 percent, respectively. In addition to Brong Ahafo and Eastern regions, since 2009 there has also been a noticeable increase in maize production from the Northern and Upper West regions (Figure 2.3). This is likely a combined result of various projects. These include the SADA (Savannah Accelerated Development Authority) program, the ADVANCE (Agricultural Development and Value Chain Enhancement) project funded by the U.S. Agency for International Development, and reintroduction of the fertilizer subsidy and the Masara N' Arziki maize outgrower scheme.

Figure 2.2 Share of maize production by region, 2012–2014



Source: Raw data from Statistics, Research and Information Directorate, Ministry of Food and Agriculture (2015).

Figure 2.3 Trends in regional maize production, 2000–2014, in tons



Source: Raw data from Statistics, Research and Information Directorate, Ministry of Food and Agriculture (2015).

Obatanpa, the white quality protein maize variety released in 1992, accounted for 41 percent of maize area in 2012, and about 98 percent of total certified maize seed sales in recent years (Ragasa et al. 2013). This is by far the most popular maize variety in Ghana. Other older modern varieties, released in the 1970s and 1980s, accounted for 10 percent of maize area. Newer open-pollinated varieties and local hybrids accounted for 1 percent. Imported hybrids accounted for roughly 1 percent to 3 percent of maize area (Ragasa et al. 2013). More recent interviews and surveys suggest that adoption of hybrid seeds remains low, at less than 5 percent.

There are ten open-pollinated varieties (OPVs) (including Obatanpa) and two varieties of local hybrid maize seed available for farmers to choose from, based on certified seed production data and interviews conducted by AGRA (the Alliance for a Green Revolution in Africa) and IFPRI. Two OPVs and two hybrids available are yellow maize varieties. There were 11 new varieties released in 2012 and

2015, but most are still in the breeder seed production stage. Three imported hybrids (white Pan53, yellow Pan12, and yellow Pioneer 30Y87) are available in input stores but only in small quantities. Pannar varieties are accessible mainly through the Masara outgrower scheme, which became concentrated largely in the Upper West Region after it had been scaled down in the Northern Region and was unsuccessful in the Brong Ahafo and Ashanti regions. Pioneer 30Y87 is the most promising variety in terms of yield performance based on on-farm trials and demonstrations; its yield advantage over the popular Obatanpa is 50 percent to 100 percent.

At the national level, there are no reliable data on maize used in animal feed or how much is consumed. An often-cited document is WABS (2008). Based on household surveys, it estimates that in Ghana, household consumption on a subsistence level accounted for 57 percent of total maize production; poultry and fish feed consumption, 13 percent; and maize traded for human consumption, 30 percent (Table 2.1). WABS (2008) indicates that these data might have overestimated the maize used for own home food consumption and underestimated the maize that is traded.

Table 2.1 Estimates of consumption of white maize produced in Ghana, 2006

Ton	Production/consumption	Total consumption
1,189,000	Total national production	
675,000	Household consumption at a subsistence level	57%
150,000	Poultry and fish feed	13%
170,000	Formally traded for human consumption (mostly wholesale)	14%
194,000	Informally traded for human consumption	16%

Source: WABS (2008).

The government estimates that 85 percent of all maize grown in Ghana is destined for human consumption; the remaining 15 percent is used for the animal feed sector, which comprises mainly poultry (FAO 2014). Data from major feed mills in Ghana indicate that about 250,000 metric tons of maize is used for poultry feed annually (FAO 2012). This is in line with the data collected by WABS (2008) on consumption of white maize in 2006, when the poultry industry absorbed 170,000 metric tons (Table 2.1) of domestic production. Based on this study's assessment of the poultry feed industry, described in more detail below, the maize used annually would be at most about 140,000 metric tons. Official data on maize imports from 2005–2014 collected by the Ministry of Food and Agriculture (MoFA) vary greatly from year to year—from zero in 2013 to 113,000 metric tons in 2012—and are claimed to be mostly yellow maize used primarily by feed millers and poultry farms. This shows average yearly official maize imports amounting to 31,000 metric tons, which indicates that most of the crop used by the poultry feed sector is locally produced. Angelucci (2012) suggests that informal imports of maize may also be substantial. Field data collected for this paper show that the ratio of yellow maize to white maize is 2.5:1, based on the storage and use records of feed mills. Assuming all yellow maize used by the feed industry is imported would suggest that maize imports (official and unofficial) are actually about 100,000 metric tons per year.

3. GHANA'S POULTRY SECTOR

Production

The development of the poultry industry in Ghana has gone through two distinct phases: increasing production from the 1960s through the mid-1980s to meet local demand, and steeply reducing production after this period. This is often attributed to the effects of market liberalization and subsequent increases in imported poultry meat. Domestic production formed the major share of poultry products available on the domestic market in the 1960s and 1970s. The last full poultry census in 2009[2] estimated that there were a little over 28 million chickens[3] (broilers, cockerels, and layers) in the country. Anecdotal evidence would suggest that the poultry population has not increased much in the past decade, given the number of large-scale commercial farms that are reported to have gone out of business or to have drastically reduced their bird populations.

The regional distribution of the poultry population is shown in Table 3.1. Poultry production is concentrated in the middle belt, primarily in the Ashanti and Brong Ahafo regions; these account for close to 70 percent of total poultry production. The middle belt offers the most conducive environment for raising chickens: moderate temperatures compared with the more humid south and the dryer, hotter northern regions. As noted in the previous section, the middle belt is also the main maize-growing area in Ghana, giving poultry production in this area the added advantage of being close to the primary feed ingredient.

Table 3.1 Poultry population estimates (2009), by region

Region	Number of birds on commercial farms (Sector 2 and Sector 3 farms)	Number of birds in backyard production systems (Sector 4 farms)	Total
Ashanti	3,514,000	5,912,618	9,426,618
Brong Ahafo	2,554,000	7,478,871	10,032,871
Central	572,000	268,066	840,066
Eastern	770,000	2,421,801	3,191,801
Greater Accra	2,190,000	324,363	2,514,363
Northern	30,000	321,297	351,297
Upper East	190,000	389,743	579,743
Upper West	0	33,000	-
Volta	34,000	220,155	254,155
Western	234,000	667,741	901,741
Total	10,121,000	17,971,655	28,092,655

Source: Authors' calculations based on data from the FAO (2014).
Note: (1) Estimates of the number of birds on backyard and commercial farms are based on the regional distribution of poultry production systems (FAO 2014), coupled with the following assumption: On average, Sector 1 farms hold 120,000 birds per farm; Sector 2 farms hold 10,0000 birds in the Ashanti, Brong Ahafo, Eastern, and Greater Accra regions and 5,000 birds in all other regions; and Sector 3 farms, hold 2,000 birds in the Ashanti, Brong Ahafo, Eastern, and Greater Accra regions and 1,000 birds in all other regions.

[2] The United States Agency for International Development sponsored a poultry census conducted in late 2015/early 2016, the results of which have yet to be publicly released.

[3] While the term *poultry* sometimes refers to chickens and other domestic bird species (for example, ducks, guinea fowls, and turkeys), in this paper we use the term to refer only to chickens, which make up around 77 percent of the overall domestic bird population and are the main subject of policy discussions on the poultry sector.

Poultry production is typically classified using the FAO international classification system, which consists of four farming systems or "Sectors" depending on the production system, access to infrastructure, and access to markets.[4] Few farms in Ghana may be accurately characterized as Sector 1 farms, which typically have a high level of biosecurity, industrial and integrated production systems, and production for export. The Veterinary Services Directorate classifies five farms in the Ashanti Region and one farm in the Brong Ahafo Region as Sector 1 operations, though only one or two would fit the full description. Commercial farms in Sectors 2 and 3 are more common, with birds held almost exclusively indoors, moderate levels of biosecurity, and production targeted at urban markets within Ghana.

Commercial poultry production (Sector 2 and Sector 3) is carried out predominantly on a small scale (50 birds to 5,000 birds). By some official estimates, this type of production makes up 60 percent to 80 percent of national poultry production (Aning 2006; MoFA 2011). Backyard poultry farming (Sector 4) takes place mainly in rural and peri-urban areas. Currently, nearly half of rural households keep poultry, compared with less than one-fifth of urban households. The share of rural households keeping poultry has remained fairly stable over time—58 percent in 1991/1992, 46 percent in 1998-1999, 51 percent in 2005/2006, and 53 percent in 2012/2013.[5] Large-scale commercial poultry operations in Ghana are engaged almost exclusively in egg production, with limited seasonal production of broilers for festive occasions.

Production Costs

In this subsection we present two pieces of information on poultry production costs—a breakdown of total costs and an assessment of scale impacts. Data are drawn from interviews held in August 2015 with 36 poultry-sector actors (farmers, input dealers, ministry officials, and traders) in the Ashanti and Brong Ahafo regions. The survey focused on egg production. The cost of producing eggs starts with the acquisition and placement of DOCs through feeding them for up to eight weeks, brooding and feeding pullets from eight weeks until laying starts at 16 to 20 weeks, and, finally, maintaining layers during the egg production cycle. Other typical costs include nonfeed costs of operating the farm such as salaries, electricity, water, communication, local government levies, and transportation.

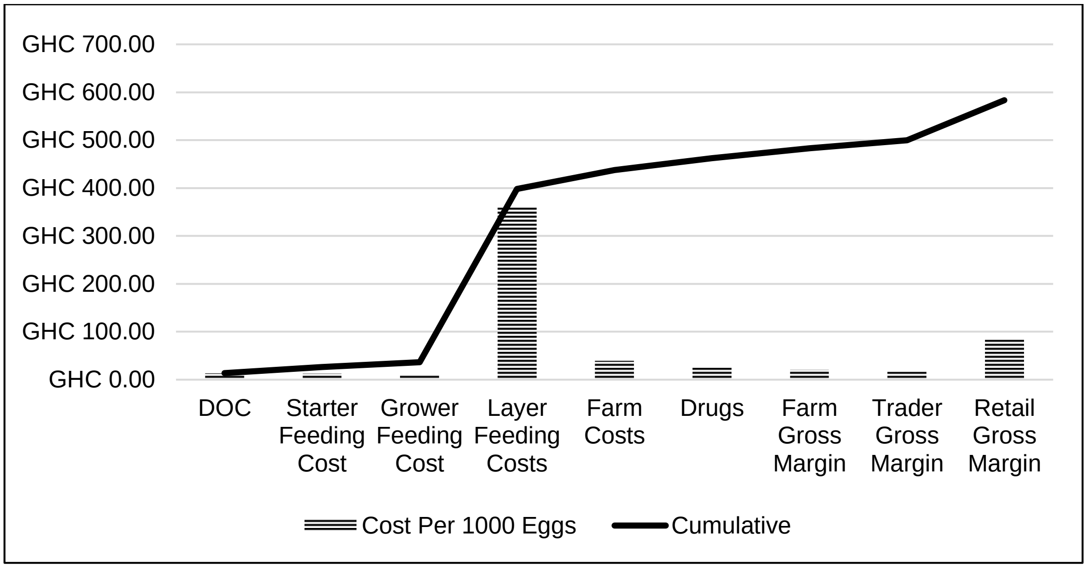
Figure 3.1 shows the costs and margins for egg production in selected farms. These calculations assume that a bird will lay about 0.71 eggs/day on average.[6] Farmers turn out to have very low profit margins (about 4.3 percent), though this can fluctuate due to production shortfalls (for example, from poultry disease outbreaks or changes in feed use and quality) and seasonal movements in market demand when eggs have to remain on farms for several days. Retailers appear to fetch higher profit margins relative to wholesalers as shown in Figure 3.1. An important thing to note, however, is the high share of feed costs to poultry egg production (about 83.4 percent in this example), and not very different from others' estimates (for instance, see Ravindran 2013).

[4] Available at http://www.fao.org/docs/eims/upload/214190/ProductionSystemsCharacteristics.pdf.

[5] Authors' estimates based on Ghana Living Standards Survey (GLSS) rounds 3, 4, 5, and 6 (GSS 1992; 2001; 2006; 2012).

[6] These assumptions are based on farmers' reported egg production levels from the field surveys, which were similar to industry reports of egg production rates (van Horne 2014; van Horne and Bondt 2014).

Figure 3.1 Egg production costs (GHC per kg of egg weight)



Source: Authors' calculations based on field data.
Note: DOC = day-old chicks; GHC = Ghanaian cedi. In Table 3.2, we illustrate scale impacts by reporting production costs from three farms: a small-scale farm that held 2,800 birds at the time of the field visit, a farm with about 32,000 laying birds that could be classified as a medium-scale operation, and a larger-scale farm with 150,000 birds. Although the data did not come from a statistically based sample and therefore may not represent the standard populations of poultry farms, interviews with value chain participants and other farmers indicated that these costs are typical. While Table 3.2 shows similar feed costs across the different scales, the data suggest some differences in farm costs depending on scale of production. These costs include wages, land rents, food for workers, local government levies, transport, electricity, water, and phones. For larger farms these costs are relatively low, about GH¢0.01 per egg produced; for smaller farms, approximately GH¢0.03 per egg. While this difference may seem insignificant, it amounts to a difference of GH¢50 per day, or about GH¢1,500 per month of additional costs for a smaller-scale operation.

Table 3.2 Egg farm production costs

Farm	Farm size (number of birds)	Feed consumption (kg/bird/day)	Production (eggs/day)	Feed costs (GHC/bird/day)	Non-feed costs (GHC/day)	Production cost/egg (GHC)
1	2,800	128	2,520	0.20	80	0.260
2	32,000	125	8,220	0.22	772	0.095
3	150,000	100	75,000	0.18	1102	0.366

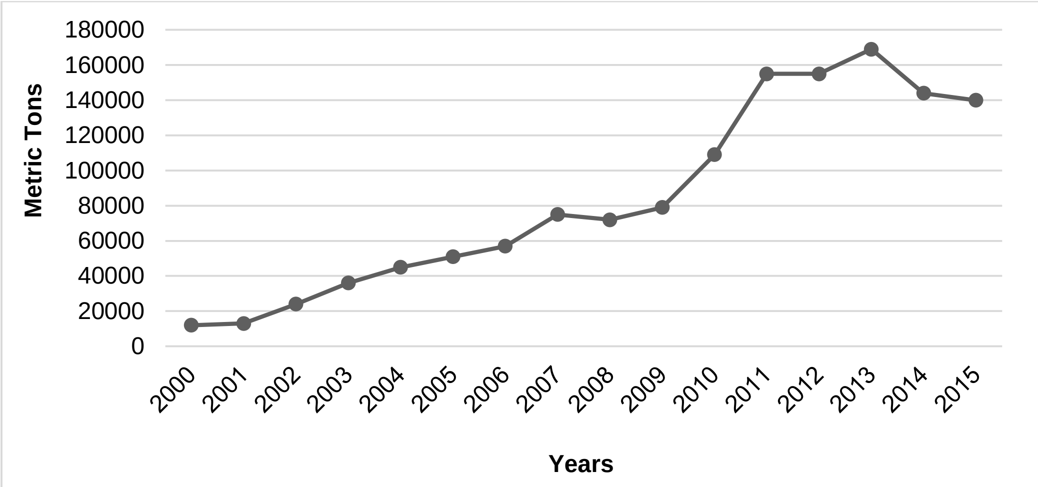
Source: Authors' computations based on farm data.
Note: GHC = Ghanaian cedi.

Consumption

The share of expenditure on poultry products in total food expenditure increased from 3 percent in 1991/1992, to 8 percent in 2012/2013.[7] Although consumption of chicken meat has increased over time, the rising demand seems to have been met primarily through imports. While imports constituted only 12 percent of the total domestic supply of poultry meat in 1961, this figure rose to 44 percent in 1990 and had reached about 80 percent by 2011 (FAO 2010). The share of domestic supply in broiler production dropped from 80 percent in 2000 to only 10 percent in 2010 (USDA 2011). Since 2000, imports of chicken meat have risen sharply (Figure 3.2). Imports come from the main poultry-exporting countries, such as Brazil, EU countries, and the United States.

[7] Authors' estimates based on data from the Ghana Living Standards Survey rounds 3 and 6 (GSS 1992; 2012).

Figure 3.2 Imports of broiler meat into Ghana since 2000



Source: USDA (2015).

An important distinction exists between the product format sales for imported and domestically produced chicken meats. The latter are sold typically in live bird markets. Customers either purchase the birds for slaughter at home, or as is increasingly common in urban areas, retailers provide in situ slaughtering and primary processing (de-feathering and cleaning but not cutting). The birds are usually spent layers[8], but broilers are also available during festive seasons. On the other hand, imported meat is sold frozen and cut into parts, usually consisting of halves or quarters. The popularity of frozen chicken parts in the market suggests that there is not necessarily a consumer preference for live birds. Domestic producers could be competitive if they faced lower production costs and if there were adequate processing and refrigeration facilities for domestic birds. There is currently only one major processing plant in Accra and three in Kumasi, all of which operate below capacity.

Considering average measures, consumption of both poultry products—chicken meat and eggs—has increased over time. Meat consumption increased from 1.27 kg per capita in 1991/1992 to 7.98 kg per capita in 2011/2012, higher than the average of 6.2 kg per capita for African countries in 2011.[9] Egg consumption almost doubled, from 0.56 kg per capita to 1.2 kg per capita, over the same period (Table 3.3). The share of poultry meat in the overall domestic supply of meat increased from 11 percent in 1969/1970 to 30 percent in the late 1990s and 66 percent in 2010/2011.

[8] These are layer birds whose egg production has slowed down considerably. In Ghana, most farmers report that birds quit laying eggs at a commercially viable rate after about 72 weeks.

[9] From *Global Poultry Trends: Upward Trend in Chicken Meat Consumption in Africa, Oceana*, The Poultry Site:http://www.thepoultrysite.com/articles/3327/global-poultry-trends-upward-trend-in-chicken-meat-consumption-in-africa-oceania/. Accessed on August 22, 2016.

Table 3.3 Average annual per capita consumption of poultry products

Year	National population ('000)*	Poultry meat supply as food (tons)*	Annual per capita consumption of poultry meat (kg)**	Egg supply as food (tons)*	Annual per capita consumption of eggs (kg)**
1961	6866.55	5582	0.81	3248	0.47
1965	7710.55	7675	1.00	4291	0.56
1971	8827.27	9102	1.03	6169	0.70
1975	9831.41	10228	1.04	7590	0.77
1981	11117.61	9117	0.82	8190	0.74
1985	12716.24	6100	0.48	5475	0.43
1991	15042.74	19076	1.27	8477	0.56
1995	16760.99	19968	1.19	10174	0.61
2001	19293.8	33224	1.72	16769	0.87
2005	21389.51	81260	3.80	18967	0.89
2011	24928.5	198835	7.98	29834	1.20

Source: FAO Corporate Statistical Database (FAO 2015).
Note: ***Calculations by authors: supply as food divided by total population.

4. FEED SECTOR ASSESSMENT

Approach

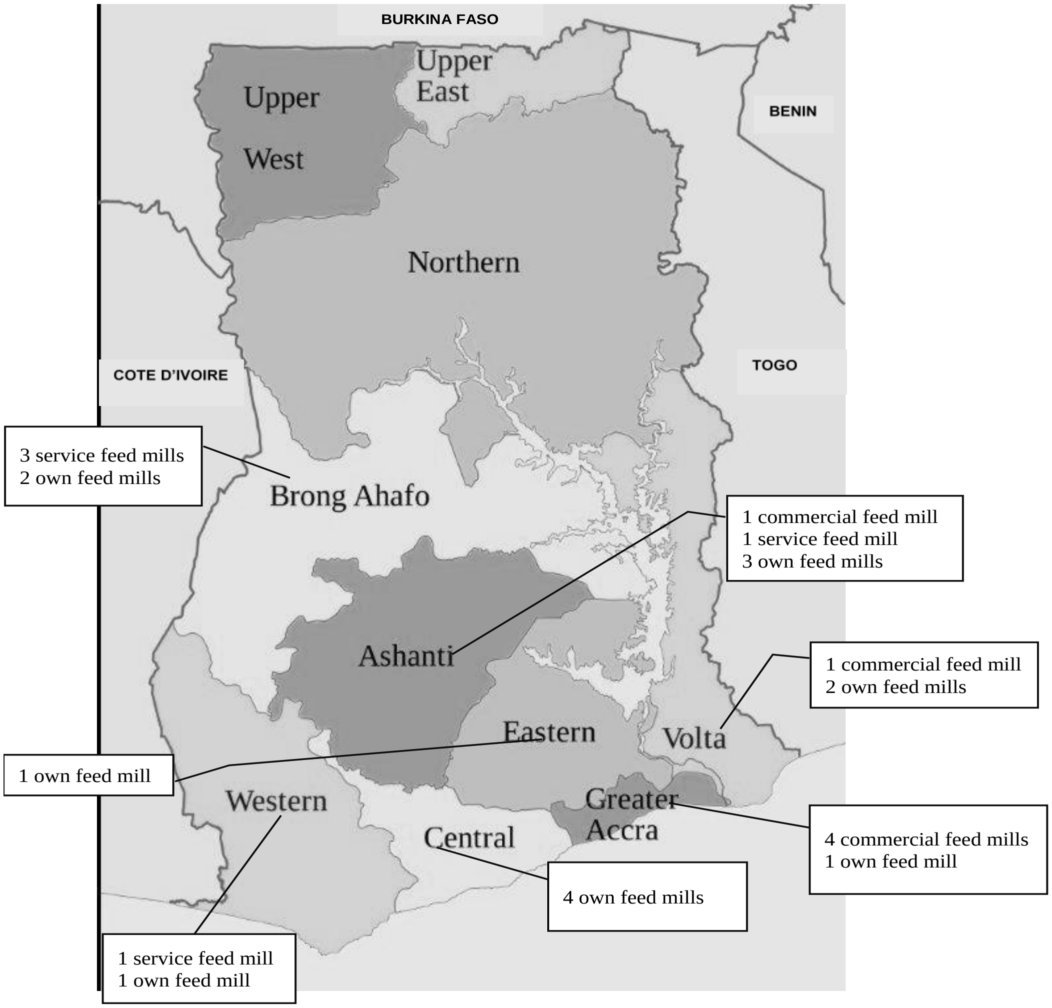
The field assessment took place from May to July 2016. The study used a structured questionnaire to collect information from feed millers. Additional information came from unstructured, in-depth interviews and field observations with selected feed millers and knowledgeable industry sources, such as input suppliers and customers. We classified feed mills into three categories: (1) commercial feed mills, (2) service feed mills, and (3) own feed mills. Commercial feed mills process feed solely for commercial sale purposes, service feed mills produce feed based only on the customized needs of customers, and own feed mills are those integrated with on-farm livestock rearing.

Before we began the field activities, we sought out available records on feed mills to generate an expected sample size. We expected this to be a small number, as the number of operational feed mills is reported to have dropped from 30 in 1988 to 14 in 2010 (FAO 2014). The Ghana Feed Millers Association supplied an initial list of six commercial feed mills that were known to be in operation. We interviewed workers at these feed mills and used a snowball sampling technique[10] to identify additional units. In addition, we relied on information from the Veterinary Service Department of the MoFA and regional extension officers to identify service and own feed mills. Using this approach, the study identified 26 feed mills in seven of the 10 administrative regions of Ghana (Figure 4.1). Two target respondents did not participate in the survey, one citing survey fatigue, the other to protect the confidentiality of his operations. We confirmed from reliable sources that there are currently no known commercial or service feed mills operating in the remaining three regions—the Northern, Upper East, and Upper West regions.

Interviews were conducted with participants at their convenience in sessions lasting between 60 and 90 minutes. At each feed mill, the research team interviewed key personnel such as owners, managers, and accountants. In five cases, the information was not readily available but was provided at a second interview on site or through a phone call. Interviews were conducted in English and Twi, a local Ghanaian language. The interview questions covered feed mill ownership and operations, equipment use, costs and assets, inputs and outputs, constraints, and contractual arrangements with suppliers and customers.

[10] The snowball sampling technique is a non-probability sampling method that involves collecting data on the few members of the target population that can be located, and asking those individuals to provide information needed to locate other members of that population.

Figure 4.1 Locations of feed mills interviewed during survey



Source: Authors' calculations.
Note: Administrative boundaries based on map from Wikimedia Commons.

Findings

This section discusses in detail the findings from the feed sector assessment. The first subsection describes the structure of the poultry feed industry in Ghana. A second subsection provides information on the ingredients used in feed production. The third subsection lays out the costs and prices involved in feed production, and a fourth subsection summarizes the main technology issues, constraints facing the industry, and policy responses.

Structure of the Feed Industry

Industry sources report that 40 percent to 55 percent of feed used in the country comes from commercial feed mills. The remainder is supplied by service feed mills (an estimated 3 percent to 10 percent of the market, mostly for small-scale farms), and own feed mills, which produce about as much as commercial feed mills. The survey covered all six commercial feed mills known to be operating in Ghana, five service feed mills, and 14 own farm feed mills. In Table 4.1 we report the location, capacity, customer base (for commercial and service feed mills), and livestock holding (for own feed mills) for feed mills interviewed during the survey.

Table 4.1 Feed mills interviewed during survey

Name	Region	Capacity (tons/hour)	Estimated average weekly production (tons)	Typical number of customers per week
		Commercial feed mills		
Agricare	Ashanti	16	200	25 from mill gate, unknown from sales agents
ESSAR-AGRO	Greater Accra	20	-	-
GAFCO	Greater Accra	200	-	-
GAPFA	Greater Accra	13	77	581
Kosher Feed Mill	Greater Accra	2	40	40
Tantra	Volta	1.5	9	15
		Service feed mills		
Aduse-Poku Farms and Agro Processing	Ashanti	2	5	10
Asante Farms	Brong Ahafo	3.5	80	10
Goodman	Brong Ahafo	1.5	100	15
McEdward Farms	Western	2	60	12
Tumi Wura	Brong Ahafo	2	13	10
		Own feed mills		
				Livestock population
Akorlor Farms	Volta	2	-	Poultry 10,000, goat 15
AMASS Farm	Greater-Accra	2	20	Poultry 9600
Atta Mills Farm	Central	0.5	2	Poultry 600, pigs 184, cattle 90
BM Unity Farm	Brong Ahafo	1.5	12	Poultry 16,000
Fosuka Farms	Ashanti	16	32	Poultry 76,000
Genesis Farms Ltd.	Ashanti	20	77	Poultry 80,000, pigs 1,330
Golden Acre	Central	1	2	Poultry 2,000
KM Unity Farm	Brong Ahafo	3	30	Poultry 10,200
Kwoffie's Farm	Central	0.75	1.5	Poultry 300
Sam O Farms	Eastern	1	3	
Tex Farms	Central	1	2	Poultry 2520, pigs 86
TonyMens Farm	Western	1.5	-	Poultry 6,500

Source: Authors' compilation based on field data.
Note: GAFCO = Ghana Agro Food Company; Greater Accra Poultry Farmers Association.

Commercial Feed Mills

Commercial feed mills produce a standard mix of feed for sale at the mill gate, or through agents in depots scattered around the country. Four of the six commercial feed mills are clustered around the capital, Accra, and the neighboring city of Tema, and one each is located in the Ashanti and Volta regions. The preference for locating around Accra is driven by the proximity of the Tema Port, which serves as the entry for imported ingredients. In addition, within the middle belt of Ghana, where large-scale poultry production is concentrated, the bulk of feed is produced on-farm in integrated systems. This creates intense competition for commercial feed mills in the middle belt. On the other hand, southern Ghana hosts many of the medium-scale poultry farmers who are the main customers for commercial feed mills.

The six commercial mills represent a varied mix. For example, the oldest has been in operation since 1969; the youngest, since 1991. The commercial feed sector is dominated by one large-scale producer, the Ghana Agro Food Company (GAFCO), located in Tema, which has the highest capacity at 200 tons/hour.[11] Two commercial mills reported production capacities of 1.5 tons/hr. and 2 tons/hr.

[11] GAFCO holds a reported 70 percent of the commercial milling market and about 20 percent of the overall market for livestock feed.

Between these extremes are three mills with capacities of 13 tons/hr., 16 tons/hr., and 20 tons/hr., respectively. The number of customers per week ranges from 15 to 581 poultry farmers.

The commercial feed mills generally operate at 70 percent to 80 percent of their capacity. Although commercial feed mills are mainly in business to produce standard feed for sale, two mills reported that they produce feed for a few selected customers on a special-order basis for stressed or ill livestock. Feed mills such as GAFCO and ESSAR-AGRO sell other feed ingredients.

The commercial feed mill industry is formally regulated. All have licenses, registrations, and certifications from government agencies, such as the Environmental Protection Agency, the Registrar-General's Department, the Factory Inspectorate, and the International Organization of Standardization.[12] Five of the six commercial mills are members of the Ghana Feed Millers Association.

Service Feed Mills

Service feed mills, which accept feed ingredients from farmers and produce a customized feed mix, typically serve small-scale poultry producers. The survey included five service feed mills in the Ashanti, Brong Ahafo, and Western regions. Compared with the commercial mills, the service mills are a more recent phenomenon—the oldest has been in operation only since 2008. Two of the service mills are registered with the Registrar-General's Department. Although none are part of the Ghana Feed Millers Association, two reported being part of a feed millers association in their locality. The capacity of service feed mills ranges from 1.5 tons/ hour to 3.5 tons/ hour, and the tonnage produced weekly is between 5 tons and 100 tons. Compared with commercial mills, service mills serve a small customer base, with about 10 to 15 customers per week.

Own Feed Mills

Own feed mills, which have integrated feed milling into livestock production, are increasingly becoming the norm in Ghana, especially in the major poultry-producing areas of the Ashanti and Brong Ahafo regions. We interviewed 14 own feed millers who operate near or on their farms. These mills process primarily feed for livestock, which usually includes poultry, sheep, goats, and pigs. The capacity of the own farm feed mills ranged between 0.75 tons/hour to 20 tons/hour. These mills usually produce feed only when needed. Due to disease risks, integrated farms are reluctant to sell feed to other farms.

Own feed milling is not as closely regulated as commercial and service milling. With the exception of one, these mills do not have nonfarm businesses, licenses, registrations, or certifications. Own farm feed mills tend to be registered for their livestock farms, but no separate registration for the operation of a feed mill.

Feed Ingredients

Feed mixes in Ghana are usually made up of 55 percent to 60 percent maize (white or yellow); 15 percent to 20 percent soy meal; 10 percent wheat bran; 5 percent to 8 percent fishmeal; small quantities of optional ingredients such as oyster shells, salt, copra cake, palm kernel cake, cotton seed cake, premixes, concentrates, toxin binders; and additives such as dicalcium, lysine, methionine, and mycofix.[13] The predominant use of maize in feed production and the constitution of feed in general follow the standards used in other developing countries (Ravindran 2013). For our survey, four out of six commercial feed mills, three out of five service feed mills, and 13 out of 14 own farm feed mills shared data on ingredients used in feed production. Table 4.2 presents a list of ingredients and reported use by feed mill type.

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[12] Additional certifications come from Hazard Analysis Critical points, the Global Gap, the Ghana Grains Council, and the Registrar of Commerce.

[13] Part of the information in this section is derived from key informant interviews conducted in August 2015.

Table 4.2 Sources and use of feed ingredients

Ingredient	Main sources	Type of feed mill	Number of mills using ingredient
White maize	Purchased locally from open market, Premium Foods Limited	Commercial	3 out of 4
		Service	2 out of 3
		Own Feed mill	9 out of 13
Yellow maize	Imported from South America (Argentina, Brazil)	Commercial	4 out of 4
		Service	2 out of 3
		Own Feed mill	12 out of 13
Soybean (from local sources)	Traders (Ghana Nuts, Dragon Farms, Vestor Oil)	Commercial	2 out of 3
		Service	3 out of 3
		Own Feed mill	3 out of 13
Soybean (imported)	Imported From Uruguay by Intergrow, GAFCO	Commercial	3 out of 4
		Service	3 out of 3
		Own Feed mill	11 out of 13
Oyster shells	Purchased locally from open market and Wildstar	Commercial	4 out of 4
		Service	3 out of 3
		Own Feed mill	11 out of 13
Fishmeal	Imported from the United States and Côte D'Ivoire or purchased locally	Commercial	4 out of 4
		Service	2 out of 3
		Own Feed mill	8 out of 13
Palm kernel cake	Purchased locally from open market	Commercial	2 out of 4
		Service	0 out of 3
		Own Feed mill	2 out of 13
Salt	Imported from Côte D'Ivoire, and purchased locally from open market	Commercial	4 out of 4
		Service	3 out of 3
		Own Feed mill	13 out of 13
Toxin Binder	Imported from Belgium, Netherlands, Germany	Commercial	4 out of 4
		Service	3 out of 3
		Own Feed mill	13 out of 13
Layer Premix	Imported from Belgium, Germany, Netherlands,	Commercial	2 out of 4
		Service	1 out of 3
		Own Feed mill	12 out 13
Hendrix (5%, 25%)		Commercial	1 out of 4
		Service	1 out of 3
		Own Feed mill	3 out of 13
Diacalcium		Commercial	4 out of 4
		Service	2 out 3
		Own Feed mill	6 out of 13
Lysine		Commercial	2 out of 4
		Service	1 out of 3
		Own Feed mill	6 out of 13
Methionine		Commercial	3 out of 4
		Service	1 out of 3
		Own Feed mill	4 out of 13

Source: Authors' compilation of field data.
Note: GAFCO = Ghana Agro Food Company. Ingredients are reported only if they were listed by five or more feed mills. Optional ingredients mentioned by fewer than five feed mills include copra cake, microchem, mycofix, and other enzymes.

Maize

This is the main ingredient in poultry feed. In Ghana, feed mills use both yellow and white maize for feed production. Yellow maize is imported from Argentina, Brazil, Côte D'Ivoire, Romania, and Uruguay, and is also purchased locally from companies such as Modern Agric, GAFCO, and UT logistics. White maize is locally purchased from the open market and companies such as Premium Food Limited.

Soybean

This ingredient is also vital in feed formulation and is often purchased locally from companies such as Ghana Nuts, Techiman, and Vestor Oil, as well as from the open market. Imported soybean comes from Uruguay and from companies such as Intergrow, GAFCO, and Louis Dreyfus.

Fish Meal, Wheat Bran, and Other Ingredients

Feed mills use fish meal imported from the United States or purchased locally from the Pioneer Food Company in Tema. All feed mills reported using wheat bran, salt, and toxin binders. Wheat bran is usually purchased locally from Takoradi flour mills, and is imported from companies such as Flour Mills of Ghana in Tema and Irani Brothers. Toxin binder is imported from Europe (Belgium, Germany, and the Netherlands). Salt is often purchased from the open market, and some feed mills import it from Côte D'Ivoire. Toxin binders, dicalcium, layer premix, methionine, and lysine as well as enzymes are purchased from the Veterinary Services Department or from a private company.

We observed differences in the ingredients used by the different types of mills. While commercial mills aim to produce a standard product for sale that would be widely acceptable to a range of customers, service and own feed mills can afford to produce customized feed. A few service and own feed mills use copra cake, groundnut cake, and cottonseed cake in feed production. But commercial mills have stopped using these ingredients because of rancidity, bad feed odor, and reports of digestive issues in poultry. The survey also found that own farm feed mills often do not use ingredients such as microchem, mycofix, and enzymes due to their cost. While some variation in feed composition is to be expected, it appears that commercial mills target a higher quality of feed than do service and own feed mills.

The feed mill industry is keenly attuned to quality control, as this affects the quality and quantity of eggs and meat produced by birds. This seems to be especially true of the commercial side of the industry, which routinely tests the quality of ingredients either in-house with a nutrition consultant or externally at the Food Research Institute, the Ghana Standards Authority, or university laboratories. Checks include tests for toxicity, moisture content, and protein levels. Out of the five service feed mills interviewed, two check for toxic levels of ingredients. In contrast, only two of the 14 own farm feed mills check ingredients before use.

Some feed mills have stopped using local fish meal, especially anchovies, due to adulteration by sand, stone, and wood shavings. Some also reported salmonella infection due to the poor quality of fish meal. Feed mills have also complained to suppliers with regard to ingredients such as maize, soybeans, and concentrates because of poor quality resulting in a high moisture content and moldy ingredients.

Feed mills use a variety of strategies to guard against shortfalls in the supply of ingredients. Most buy feed ingredients, especially maize, during the bumper season to store against the lean season. Other feed mills prefinance or provide credit to maize and soybeans farmers to obtain ingredients.

Volumes and Costs of Feed Production

Feed Inputs

In addition to differences in the type of ingredients used for feed formulation, there are some disparities in the quantities of the main feed ingredients used across the three categories of feed mills, as shown in Table 4.3 where we report the costs of the last ingredients purchased for feed. The quantity of white or yellow maize used ranged from 425kg to 850kg for one ton of feed. The price of white and yellow maize ranged from GHC 0.94/kg to 1.9/kg. For layer feed, millers prefer yellow to white maize because this gives the egg yolk the strong yellow color preferred by consumers. When yellow maize is not available, feed millers use carophyll, a costly additive, to achieve yellow yolk coloration. For broiler feed, white maize is preferred.

The quantity of wheat bran used ranges from 125 kg to 300 kg at a price of 0.36/kg to 0.6/kg. Commercial feed mills use more soybean (200 kg to 850 kg) and fish meal (18 kg to 40 kg) than service feed mills (150 kg to 425 kg and 3 kg, respectively) and own farm feed mills (125 kg to 500 kg and 1 kg to 4 kg, respectively). Service and own farm feed mills also use more oyster shells, salt, and toxin binders than commercial feed mills. Most commercial feed mills use vitamin premixes, while service and own farm feed mills tend to use concentrates.

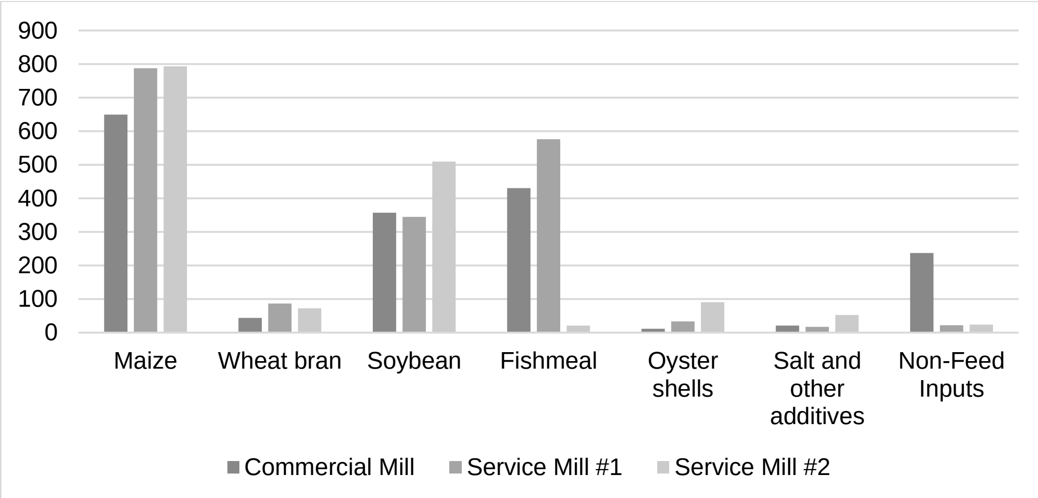
Table 4.3 Volumes and prices of feed inputs for producing one ton of feed

	Commercial		Service		Own farm	
Ingredient	Volume (kg)	Average price (GHC)/kg	Volume (kg)	Average price (GHC)/kg	Volume (kg)	Average price (GHC)/kg
White maize	600 – 800	1.1	600 – 700	1.8	500 – 850	1.6
Yellow maize	500 – 600	1.7	600	1.2	425 – 600	2.1
Wheat bran	175 – 300	0.4	125 – 300	0.6	125 – 400	0.7
Soybeans local	400 – 850	2.9	150 – 425	3.2	150 – 500	3.3
Soybeans	200 – 850	3.0	150 – 425	3.4	100 – 250	3.7
Oyster shell	19 – 80	0.4	125 – 150	0.4	75 – 150	0.4
Fish meal	18– 40	8.5	3	4.8	1 – 4	5.2
Copra cake						
	Commercial		Service		Own farm	
Ingredient	Volume (kg)	Average price (GHC)/kg	Volume (kg)	Average price (GHC)/kg	Volume (kg)	Average price (GHC)/kg
Palm kernel cake	1.5 – 2	0.3			1.1 – 1.5	0.5
Cottonseed cake					1.5 – 4	1.7
Salt	1 – 3	0.7	1.5 – 3	1.8	1 – 6	1.9
Toxin Binder	1	6.5	2 – 3	6.9	1 – 4	7.8
Layer Premix	2 – 2.5	6.9	2.5 – 100	8.5	1– 4.5	9.8
Hendrix	100	3.8			50 – 250	5.0
Diacalcium	1 – 4	5.1	1	2.6	0.3–4.5	8.0
Microchem					2	4.8
Lysine	1.5	10.7	1.5	7.0	0.2 – 3	7.5
Methionine	1	33.6			0.3–4	26.0
Mycofix	1	3.2			1.5	13.2
Enzyme	0.5	50.6			0.3	50.6

Source: Authors' calculations.
Note: GHC = Ghanaian cedi.

How do these volumes and prices of feed ingredients translate into production costs faced by feed millers? In Figure 4.2 we present the production cost structures for producing a ton of feed, for a typical commercial feed mill and two service feed mills. Based on field data, we estimate both feed and non-feed costs. Clearly, feed ingredients make up the highest share of overall production costs. If the cost of labor per month for a typical commercial feed mill is around GHC 46,000 while the average cost of other recurrent monthly expenses (such as utilities and transportation costs) is around GHC 75,000, the cost of maize purchases alone for a month would exceed GHC 340,000. Service feed mills operate generally at a lower scale, spending on average GHC 1,000 on labor per month and GHC 7,000 on recurrent monthly costs. Own feed mills averagely spend monthly amounts of GHC 2,500 on labor and GHC 28,000 on other recurrent costs, partly reflecting additional labor costs for livestock operations.

Figure 4.2 Feed production costs (GHC per ton of feed)



Source: Authors' calculations based on field data.
Note: GHC = Ghanaian Cedi.

Technology, Constraints, Policies

Technology

Feed milling technology is an important feature of the poultry industry. Minor changes in feed composition can affect egg productivity, growth rates of birds, and even mortality rates. Therefore, the field assessment included questions on the knowledge and available technologies for feed production. Feed mills appear to have substantial capacity and advanced training in the feed milling process. Respondents reported extensive training in feed milling from local universities and research institutes, as well as from countries such as Côte D'Ivoire, Israel, the Netherlands, and South Africa. Feed mills also appear to share information across firms. Some employed the services of nutritionists to formulate feed, and most reported following instructions on concentrates purchased for feed preparation.

Commercial feed mills have more advanced equipment than service and own feed mills. They have complex, fully automated, integrated mixers; the service and own feed mills tend to have locally manufactured integrated mixers that are loaded manually with ingredients. In addition, all the commercial feed mills use electronic scales to measure minute quantities of ingredients. Service and own feed mills use manual scales, which achieve a lower accuracy of measurement than that attained by commercial millers.

Constraints

For the field survey, feed mills were provided a list of potential constraints, and respondents ranked the three most pressing ones faced in feed processing. By far the most pressing constraint was high energy cost, which 29 percent of feed mills ranked as the most important constraint. A total of 20 percent ranked it as the second most important constraint, while 59 percent ranked it as one of the top three constraints (Table 4.4). Analyses of the monthly costs of operations confirmed this response. Electricity charges were the second highest recurrent cost, after haulage costs. Apart from energy costs, unreliable energy supply affects feed production. Some feed mills have had to purchase and run generators, leading to higher production costs, and others have had to stop production altogether due to power outages. Financing was the second major issue identified, specifically, lack of access to credit and its high cost when it can be found. The third issue deemed a major constraint by feed mills was the unreliability and high cost of inputs, especially maize.

Table 4.4 Constraints faced by feed mills

Constraint	Ranked most important (% of feed mills)	Ranked second most important (% of feed mills)	Ranked third most important (% of feed mills)	Ranked among top three constraints (% of feed mills)
Energy costs	29	20	10	59
Access to credit	5	12	15	32
Interest rates on loans	2	8	20	30
Input price volatility	12	8	10	30
Prices of white maize	12	4	5	21
Prices of yellow maize	17	4	0	21
Transportation costs	2	16	0	18
Price volatility of maize	0	8	10	18
Lack of capital to expand operations	2	4	10	16
Competition from other feed mills	2	0	10	12
Unreliable supply of maize	2	4	5	11
High price of imported inputs	10	0	0	10
Labor costs	0	0	5	5
Access to laboratories for testing ingredients	5	0	0	5
Low volumes of yellow maize when needed	0	4	0	4
Environmental issues	0	4	0	4
Lack of extension services for farmers	0	4	0	4

Source: Authors' compilation of responses from feed mills.

Policies and Projects

In the past, feed milling received little attention from policy makers or donor projects, and interview respondents were unaware of policies or interventions to support their operations. While the maize sector has seen several investments from donor projects (Tripp and Ragasa 2015) and the poultry sector has seen varied government interventions (Sumberg et al. 2013), feed milling has been a somewhat neglected link between the two sectors. In part, this is because the development of the maize sector has been focused more on human consumption needs and less on its role as a supplier of inputs for livestock production. Until recently, the development of improved maize hybrids by the national research system has been almost entirely for white maize. Poultry-sector interventions have either attempted to reduce imports[14] or operated on a smaller scale through projects such as the Broiler Revitalization Project, which reduces the cost of other inputs such as DOCs and drugs. However, this lack of attention to the feed milling sector may be changing as more recent government and donor efforts to improve poultry production have explicitly recognized the importance of the chain linking input production, feed milling, and poultry production.[15]

[14] Examples include the attempted tariff increase in 2003 and the more recent requirement that importers of frozen chicken purchase 30 percent of their orders locally before being granted permits.

[15] A typical example is the USDA-funded AMPLIFIES project that is aimed at increasing local production of poultry feed inputs such as soybean.

5. LIKELY EFFECTS OF POLICY CHANGES: A SPATIAL MARKET MODEL

Building on the above reviews of the maize, poultry, and feed production sectors in Ghana, we now examine more closely how changes in one sector (whether an improvement or change in output in the maize, feed, or poultry sectors) affect the entire value chain though its impact on equilibrium prices and quantities produced and demanded. In the process, the extent to which imports can be displaced by increased domestic production and competitiveness will also be explored. The analysis explicitly accounts for how the geographic location of production and demand within each of the sectors and industries in the poultry value chain determines market equilibrium prices and quantities, as well as trade flows, between locations.

We begin this section with a review of the empirical approach and assumptions made in undertaking this analysis. This is followed by a descriptive overview of the data used for the empirical analysis and validation. Results of a number of model simulations that represent various policy and investment options to stimulate the poultry sector in Ghana are then presented and discussed.

Empirical Approach and Assumptions

We chose to use a simple spatial equilibrium market model to capture the effects of a change in one sector on price and quantity changes in other sectors. The decision to use this model was also made to explicitly incorporate the spatial nature of supply and demand for poultry products and feed in Ghana, including its commodity components—maize and soybeans. This is because different patterns of intraregional trade flows are expected to occur between regions in the country, depending on the amount supplied and demanded in each location, as well as the costs associated with transporting each commodity between surplus and deficit areas.[16] The spatial equilibrium model follows in the tradition of Takayama and Judge (1964), Harker (1986), and others. Our version can be described as a seven-commodity spatial market equilibrium model for the poultry and other corresponding subsectors in the poultry industry value chain in Ghana. The primary commodities and the intermediate and final products included are white maize, yellow maize, soybeans, broiler feed, layer feed, poultry meat, and poultry eggs, all of which serve as key inputs and outputs of the poultry value chain. The grains (maize and soybeans) serve as the primary commodity inputs in the production and supply of types of poultry feed. The latter, on the other hand, is an intermediate commodity that makes up more than 70 percent of the costs associated with producing poultry meat and eggs.

Of the two types of poultry products, the poultry meat sector is the smaller and less competitive when dealing with cheaper imports from Brazil. Among the seven commodities, only feed (in its mixed form) and eggs cannot be imported from global markets. For the five commodities imported from global markets (both types of maize, soybeans, and poultry meat), we consider Ghana a "small country" importer that cannot influence the world price. In other words, the world price is considered fixed and exogenous in the model for all the relevant commodities. Imports from global markets are allowed to enter through Accra only for poultry meat (that is, via the port of Tema). We permit grains from global markets (maize and soybeans) to also pass through neighboring countries, and similarly for feed. For the regional commodities (inclusive of feed and poultry eggs), trade occurs with the adjacent neighboring countries of Cote d'Ivoire in the west, Togo in the east, and Burkina Faso in the north, through border crossings in the Brong-Ahafo, Volta, and the Upper East and West regions, respectively. All in all, trade among regions for each commodity occurs when the price difference between them reaches the full cost of transporting the commodity between the regions. Similarly, the commodities are imported when the wholesale price in a region rises as high as the import parity price for that region; they are exported when it falls as low as the region's export parity price. Further details on the model are presented in Appendix A.

[16] The Northern Region was aggregated to include the Upper East and Upper West regions due to the low poultry production in these two regions alone. We added the production figures for these two regions to the Northern Region.

To capture the linkages across subsectors in the value chain, the model equation explicitly links them together. First, the demand for feed is derived directly from the production (and, hence, domestic supply) of poultry products, linking broiler feed with poultry meat production and layer feed with egg production, respectively. A feed-conversion ratio (FCR) is used to determine the amount of feed (in metric tons) required by the poultry industry to feed 1 metric ton of its birds. For broiler chickens, we calculated this to be 2.7; for layers this was much higher at 5.2. Based on the experience in other regions of the world, both ratios are much higher than average in commercial production systems (about 2.0 for broilers in Brazil and 3.2 for egg production in the United States, for example). We later introduce lower values in some of our simulations to capture improved efficiency in poultry production.

In relation to the grains in our model, demand for yellow maize and soybeans is directly determined by the demand for grains in the feed industry. Demand for white maize, on the other hand, is dominated by national consumption demand. Therefore, it is modeled as a typical linear demand function, as are the final poultry products—chicken meat and eggs. However, because we have assumed that the demand for grains in the poultry sector is derived from the demand for grains in the feed industry, we simply add the derived amount for white maize by the broiler feed industry only. This is based on the assumption that, for the purpose of simplicity, poultry meat production prefers feed mixed with white maize while poultry layer production prefers feed mixed with yellow maize, as it adds color to the egg yolk. Both feed types use 70 percent maize and 30 percent soybeans in their mix. Although other imported additives are also used, we chose not to include these as they represent a small proportion relative to grains in the total cost of feed production (as pointed out in previous sections).

Model Data and Validation

Our model relies on actual data with respect to region specific production, consumption, and prices. Data were taken from the Ministry of Food and Agriculture (MOFA 2010) and the Ghana Statistical Services, which were used in conjunction with data from the feed-sector assessment described in this paper. Freight and transportation costs were calculated based on an expert interview to calculate an average unit cost (per metric ton and per km). Total freight costs between regions were then calculated using the unit cost and actual distances in km between regional capitals (average unit freight costs were calculated as 0.5 GHC/metric tons/km). Based on the data used, the model was calibrated to reflect the commodity markets in 2014.

Table 5.1 presents the final model data with regard to quantities consumed, produced, and imported. Note that in Ghana, white maize is used mainly for human consumption while yellow maize is used almost exclusively for poultry feed, specifically, egg production. The values for imported quantities are the residuals between supply and demand, showing that imports through Accra are mostly for poultry meat, yellow maize, and soybeans. This appears consistent with data on imports. Consistent with field observations and interviews are the imports of pre-mixed poultry feed in Brong Ahafo from Ivory Coast; sometimes even maize comes through the border.

Table 5.1 Quantities demanded, produced, and imported in the base model (1,000 Metric tons)

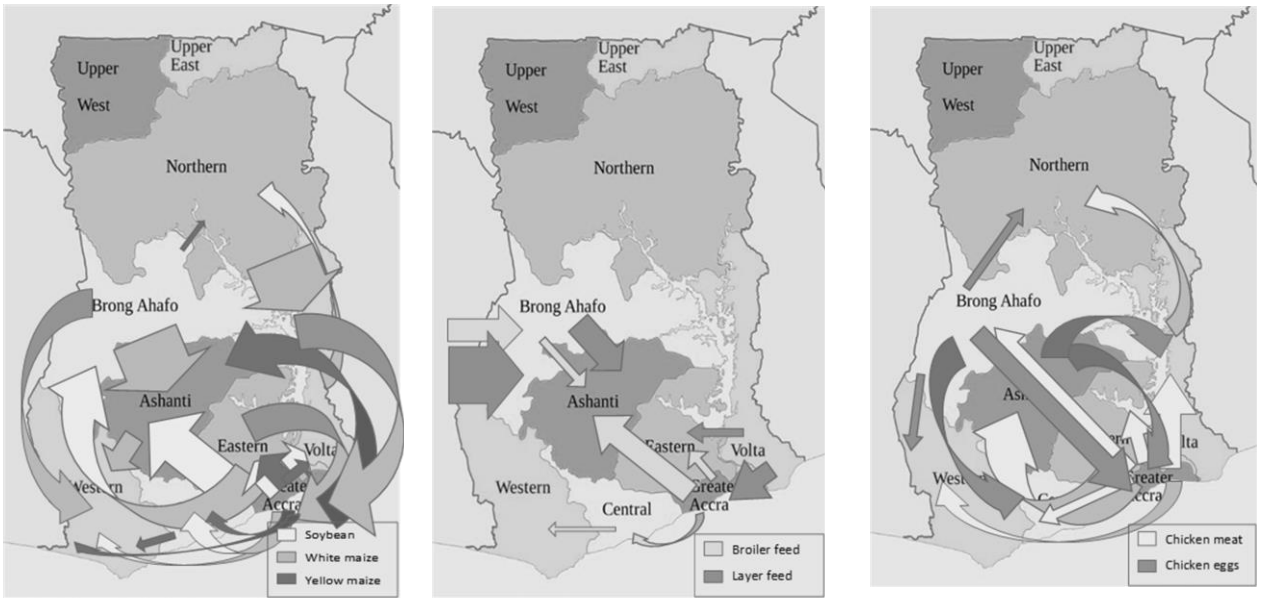
Region	Broiler feed	Layer feed	Soybeans	White maize	Yellow maize	Poultry meat	Poultry eggs
Consumption							
Accra	6.9	16.6	6.8	320.4	11.6	54.0	10.6
Ashanti	13.0	57.7	18.8	379.4	40.4	51.8	7.3
Brong Ahafo	9.0	53.1	13.8	182.4	37.2	21.4	1.5
Central	1.6	4.9	1.9	172.4	3.5	12.3	2.4
Eastern	2.6	16.3	5.3	211.5	11.4	17.4	2.5
Northern*	0.6	3.0	1.1	106.8	2.1	9.5	1.3
Volta	0.7	3.4	2.5	168.7	2.4	15.0	2.0
Western	0.4	4.5	1.5	185.0	3.2	19.5	3.0
Total	34.7	159.5	51.7	1,726.7	111.6	200.9	30.6
Production							
Accra	9.5	13.2	0.0	4.2	0.0	2.5	3.2
Ashanti	8.9	53.8	0.0	196.7	1.8	4.8	11.1
Brong Ahafo	5.8	40.2	0.0	478.8	2.8	3.3	10.2
Central	1.5	4.9	0.0	167.4	2.2	0.6	0.9
Eastern	2.3	15.3	0.0	367.2	5.0	1.0	3.1
Northern*	0.6	3.0	0.0	354.5	1.8	0.2	0.6
Volta	0.7	7.7	0.0	81.6	1.1	0.2	0.6
Western	0.4	4.5	0.0	76.3	0.0	0.2	0.9
Total	29.6	142.7	0.0	1,726.7	14.8	12.8	30.6
Imports							
Accra	0.0	0.0	51.7	0.0	62.2	188.1	0.0
Ashanti	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brong Ahafo	5.1	16.8	0.0	0.0	34.6	0.0	0.0
Central	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eastern	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Northern*	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Volta	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Western	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5.1	16.8	51.7	0.0	96.9	188.1	0.0

Source: Ghana Living Standards Survey round 6 (GSS 2012), FAOSTAT database (2010) data sources for production and consumption. For poultry, this was based on estimates from the FAO (2014).
Note: *Includes the Northern, Upper East, and Upper West regions.

From the base model, commodity trade flows can be determined based on the initial equilibrium prices and the quantities of supply and demand in each region, including those that flow in from global markets through Accra. Recall from our previous discussion that trade between regions for each commodity occurs when the price difference between them reaches the full cost of transporting the commodity between the regions. Similarly, the commodities are imported when the wholesale price in a region rises as high as the import parity price for that region, and they are exported when it falls as low as the region's export parity price. The resulting trade flow patterns in the base model are illustrated in Figure 5.1 and in more detail in Table B.4 in Appendix B.

Figure 5.1 Trade flow directions by commodity in the base model (arrows are scaled by volume)

a) Grains (soybeans and maize) **b) Feed (broiler and layer)** **c) Poultry (meat and eggs)**



Source: Author's calculations based on model results.

Figure 5.1 indicates that beginning with grains, the maize belt regions of Brong Ahafo and the North supply a large share of the maize demand in the country, flowing to the Southern regions. The Ashanti and Eastern regions also supply the Western and Accra regions, with a significant amount of maize from Brong Ahafo flowing into the Ashanti Region. From the North, the bulk of it appears to flow through the Volta Region to Accra. Much of yellow maize comes through the port of Accra from global markets. The bulk is shipped to the Ashanti, Eastern, and Volta regions, which are major layer-feed-producing regions. Soybeans follow similar patterns, though the bulk is shipped to the Brong Ahafo and Ashanti regions, which produce significant amounts of both layer and broiler feed. Production is often insufficient in the latter two regions, as evident by the flow of feed to both regions (the center map in Figure 5.1). A significant amount of feed is also being imported from Côte d'Ivoire in the Brong Ahafo Region. In the poultry sector, chicken eggs appear to flow more from the Brong Ahafo and Ashanti regions, while much of the poultry meat comes from Accra as imports from global markets. We believe these patterns in the base model are sufficiently close to actual trade patterns in Ghana today.

The initial quantities demanded and supplied in the poultry and feed production industries require some explanation. Various calculations had to be done to convert the data based on the evidence collected from the field and presented in the earlier section. First, for the supply of poultry chicken and eggs, we used estimates from the UN FAOSTAT database and a 2014 report by FAO on the poultry sector in Ghana. From the FAO study, we derived estimates of commercial poultry production for each region as a share of the total poultry production (inclusive of backyard and small enterprises). This was done to focus our study on the commercial sector and its linkages along the value chain with feed, and on some of the key imported commodities (soybeans and yellow maize). Additionally, because we are interested in assessing options for displacing poultry meat imports, it was important to focus attention on commercial production.

Second, for the supply of feed, we relied heavily on the field data collected and discussed in the previous section on feed-sector capacities, inclusive of both own production and stand-alone commercial feed producers. Estimates of total capacity of stand-alone mills, together with rough estimates of own feed production shares across all commercial poultry meat and egg producers, were used to determine the final supply of feed type by region (Table 5.2). We also assumed there had to be a sufficient supply of feed for the entire poultry production sector, aside from a few imports from Côte d'Ivoire via the Brong Ahafo Region (as our base model numbers in Table 5.1 showed).

Table 5.2 Shares of own feed production among commercial poultry meat and egg producers in each region, assumed for modeling purposes only

Regions	Eggs (MT)	Meat (MT)
Greater Accra	50%	40%
Ashanti	87%	50%
Brong Ahafo	70%	45%
Central	100%	100%
Eastern	100%	100%
Northern*	100%	100%
Volta	100%	100%
Western	100%	100%

Source: Authors' calculations
Note: MT = metric tons. * Includes the Northern, Upper East, and Upper West regions.

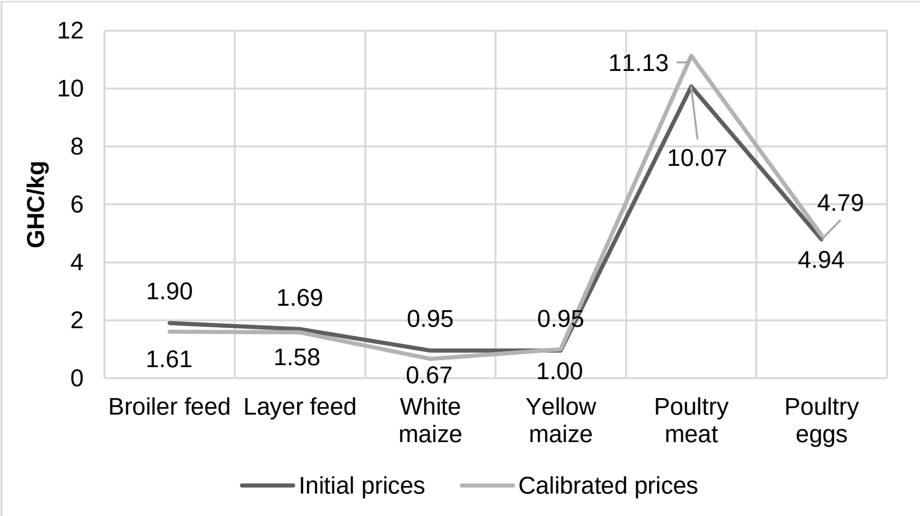
Third, demand for feed was determined by using our own calculated FCR for both poultry meat and eggs based on expert interviews in the field. The FCRs were then used to calculate total feed demand in Ghana by multiplying the ratio with our estimates of total production of poultry meat and eggs in each region. The final FCRs were calculated as follows:

<u>Production of poultry meat (broilers)</u>		
3.5 kg of feed =	1.85	kg of a full broiler (1.20 kg of meat)
FCR (feed weight/bird weight) =	1.89	(unit less, i.e., 3.5/1.85)
FCR (feed weight/meat weight) =	2.70	(unit less, i.e., 3.5/1.20)
<u>Production of eggs (layers)</u>		
1 metric ton of feed =	8,000	layers/day
1 metric ton of feed =	3,200	number of eggs per day [8,000 x 4/7]
1 kg feed =	3.2	number of eggs (3,200/1,000)
1 kg feed =	0.192	kg of eggs (i.e. 3.2 x 60 g/1,000)
FCR (feed weight/egg weight) =	5.21	(unit less, i.e., 1/0.192)

Finally, estimates for yellow maize were also calculated based on anecdotal evidence of where yellow maize is being currently grown (by region), as well as on regional shares of the national total; this was assumed to make up scarcely 1 percent of the total area for maize. Adjustments were also made to ensure that only about 15 percent of the demand for yellow maize in the feed mix demanded by the egg production industry was met by domestic production. The remainder is imported, as is evident in Ghana today.

The base model was calibrated to closely resemble the data, inclusive of the resulting equilibrium prices. When compared with actual observed values, the model performed quite well, though it was sensitive to selected parameter values of some of the price and cross-price elasticities of demand and supply for each commodity (based on a sensitivity analysis). Nevertheless, the effects were not overly significant. Figure 5.2 compares initial national average price data with those of our final calibrated model. These appear to be quite close except for poultry meat, which had to be slightly adjusted to ensure market equilibrium across the regions.

Figure 5.2 Initial and calibrated prices (national average), GHC/kg



Source**:** Data from the Ministry of Food and Agriculture and other local sources prior to calibration (price for poultry meat includes a 35 percent import tariff).

Note: GHC = Ghanaian Cedi.

Aside from initial quantities produced and consumed, prices, and unit costs of transportation, other essential parameters used in the model were the price elasticities of supply and demand. These measure the responsiveness of producers and consumers to small price changes and, therefore, define the slopes of our simple linear supply and demand functions in the model. Parameter values of these elasticities were taken from various sources, with some small adjustments during calibration to ensure model stability. Adjustments were also necessary to reflect, as much as possible, local conditions of market behavior for each type of product or commodity.

Cross price supply elasticities were also introduced to explicitly introduce any strong interrelationships among the various types of commodities along the value chain. That is, from primary inputs (grains), to an intermediate commodity mix (feed), and, finally, to the production of final poultry products (meat and eggs). For example, because a large proportion of poultry farmers mix their own feed, it was essential to establish a relationship between a change in poultry prices given a change in feed prices, as this directly affects their marginal costs and thus supply response (and vice versa). Additionally, for maize, we assumed farmers would be more sensitive to yellow maize prices when choosing how much land to allocate to the two maize types, but less so in reverse. This is because almost all the maize produced in Ghana is white maize, as it is widely consumed by the population as a food staple and, therefore, has a large market (including for own consumption) in Ghana and in neighboring countries. Yellow maize, on the other hand, is used only for poultry feed. Providing incentives to farmers to allocate more land to yellow maize depends on the relative marginal returns it provides versus other crops— and, in our case, land traditionally allocated to white maize production. To capture this in our simple model, we introduced a negative cross price elasticity only for the responsiveness of yellow maize production, given a change in white maize prices and not vice versa, as well as our assumption of a weak relationship between a change in yellow maize prices on white maize production. The final set of elasticities used in the model is summarized in Table B.1 in Appendix B.

Our primary objective for developing the Ghanaian poultry and feed sector model was to simulate various policy and investment alternatives to assess, in particular, the extent to which the poultry industry can grow and displace imports. To accomplish this, we introduce a number of simulations that shock various model parameters, as summarized in Table 5.3. The first three simulations (S1 through S3) focus explicitly on the final poultry meat and egg production industry in the value chain, followed by S4 on the intermediate feed sector, and S5 and S6 on the grain sectors (white and yellow maize, respectively). We begin by introducing an import substitution strategy by introducing protective import tariffs on chicken meat to determine the extent to which domestic producers will respond under current local conditions. This is essentially increasing the current import tariff of 35% to 45% (S1 in Table 5.3).

Table 5.3 Description of parameter shocks and model simulations

Sim	Description
Base	Calibrated model at observed values
S1	Base + Increase the poultry import tariff from 35% to 45%
S2	Base + Double national output of domestic poultry meat production (capacity expansion)
S3	Base + Improve production efficiencies of poultry industry (reducing feed-conversion ratio by 20%)
S4	Base + Double national output of domestic broiler feed and 20% increase for feed layer production
S5	Base + Increase national output of white maize production by 20% (productivity and area expansion)
S6	Base + Accelerate production of yellow maize to displace imports (8-fold increase in output)
S7	Base + Combine S2 through S6 (as an integrated poultry investment strategy)

Source: Authors' calculations.
Note: S1 = inc. poultry meat import tariff to 45 percent; S2 = doubling production of poultry meat; S3 = increased efficiency in both poultry sectors, lowering feed-conversion rate by 20 percent; S4 = doubling capacity and output of domestic broiler feed and by 20 percent for layer feed; S5 = inc. output of white maize by 20 percent; S6 = accelerating yellow maize production (a 7.7-fold increase in output); S7 = combining simulations S2 through S6.

For our next experiment, S2, we double the output of domestic poultry meat production through capacity expansion, here keeping the import tariff at its current rate of 35 percent. In S3, we focus attention on improving productivity in the poultry industry, here focusing on production efficiencies by reducing the FCRs for both broilers and layer chickens by 20 percent. Next, we double the national output of domestic broiler feed and increase feed layer production by 20 percent (S4). In S5, we increase national output of white maize production by 20 percent through productivity enhancements and area expansion. We do the same for yellow maize (S6), but here accelerate production in order to displace imports altogether, which turns out to require an 8-fold increase in output. Finally, in S7, we combine all the policy shocks from S2 through S6 as part of an integrated poultry investment strategy—excluding a change in import tariffs. Results from these various simulations are presented and discussed in the next section.

Model Results

Results with regard to changes in equilibrium price, quantities, and trade relative to the base model for all six simulations are presented in Table 5.3. The first thing to notice is that raising the poultry meat import tariff from 35 percent to 45 percent (S1) has the expected effect of simply raising domestic prices, given such a high dependency on imports, by 6.3 percent, as shown in Table 5.4. Local feed and poultry producers naturally benefit as import volumes fall by 9.8 percent, with poultry meat production output rising by 11.9 percent and 8.3 percent for broiler feed producers. To measure the effect of this policy change (and others to follow) on economic welfare, Figures 5.3 and 5.4 show this for producers and final consumers.

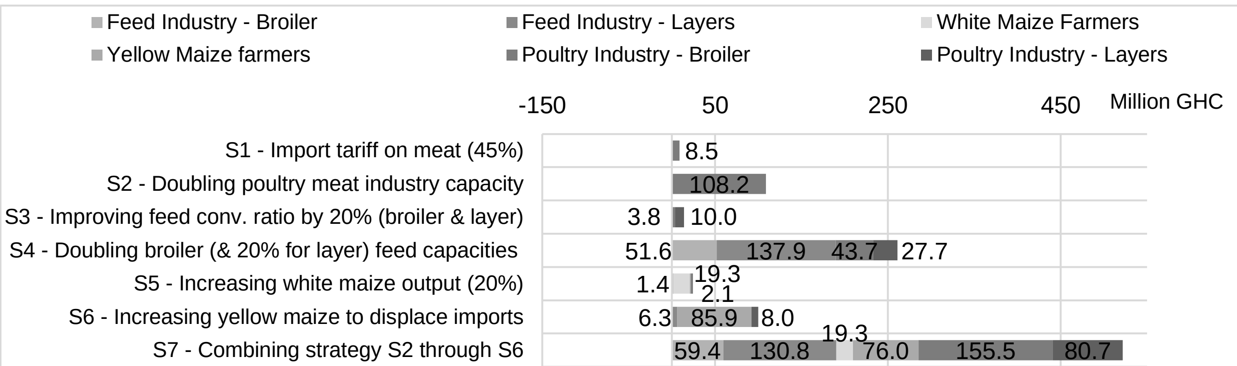
Table 5.4 Model results for all six simulations (% changes aggregated to national level)

Variable	Simulation						
	S1	S2	S3	S4	S5	S6	S7
Price changes (%)							
Feed (broiler)	0.2%	6.4%	-4.9%	-35.2%	-3.4%	0.0%	-31.7%
Feed (layer)	0.0%	0.0%	-5.3%	-10.6%	-0.2%	-4.6%	-25.6%
Soybeans	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Maize (white)	0.0%	0.3%	-0.1%	0.1%	-8.3%	0.0%	-8.3%
Maize (yellow)	0.0%	0.0%	-0.5%	0.0%	-0.4%	-11.4%	-20.6%
Poultry (meat)	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Poultry (eggs)	0.0%	0.0%	-1.4%	-1.8%	0.0%	-1.0%	-1.8%
Demand changes (%)							
Feed (broiler)	11.9%	100.0%	-16.9%	39.4%	2.1%	0.0%	90.8%
Feed (layer)	0.0%	0.0%	-18.4%	7.0%	0.0%	1.5%	0.7%
Soybeans	1.5%	2.0%	-9.3%	34.6%	2.4%	4.6%	39.7%
Maize (white)	0.1%	0.8%	-0.1%	0.3%	16.2%	0.0%	17.4%
Maize (yellow)	0.0%	0.0%	-18.4%	7.0%	0.0%	1.5%	0.7%
Poultry (meat)	-8.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Poultry (eggs)	0.0%	0.0%	2.0%	2.7%	0.0%	1.5%	2.7%
Prod. changes (%)							
Feed (broiler)	8.7%	11.9%	-7.4%	106.6%	13.7%	0.0%	133.2%
Feed (layer)	0.0%	0.0%	-9.7%	19.6%	0.0%	5.6%	20.2%
Soybeans	-	-	-	-	-	-	-
Maize (white)	0.1%	0.8%	-0.1%	0.3%	21.6%	0.0%	21.6%
Maize (yellow)	-0.1%	-0.6%	-0.9%	-0.2%	16.1%	667.5%	661.9%
Poultry (meat)	11.9%	100.0%	3.8%	39.4%	2.1%	0.0%	138.5%
Poultry (eggs)	0.0%	0.0%	2.0%	7.0%	0.0%	1.5%	25.9%
Imports (MT)							
Feed (broiler)	6,635	36,298	1,383	0	1,762	5,084	0
Feed (layer)	16,777	16,777	1,303	0	16,762	11,157	0
Soybeans	52,472	52,751	46,892	69,575	52,925	54,079	72,209
Maize (yellow)	96,879	96,961	76,482	104,755	94,516	34	0
Poultry (meat)	170,197	175,206	187,563	182,996	187,786	188,056	170,260
Import changes (%)							
Feed (broiler)	30.5%	613.9%	-72.8%	-100.0%	-65.4%	0.0%	-100.0%
Feed (layer)	0.0%	0.0%	-92.2%	-100.0%	-0.1%	-33.5%	-100.0%
Soybeans	1.5%	2.0%	-9.3%	34.6%	2.4%	4.6%	39.7%
Maize (yellow)	0.0%	0.1%	-21.0%	8.1%	-2.4%	-100.0%	-100.0%
Poultry (meat)	-9.5%	-6.8%	-0.3%	-2.7%	-0.1%	0.0%	-9.5%
Exports (MT)							
Feed (broiler)	0	0	0	12,842	0	0	2,876
Feed (layer)	0	0	0	0	0	0	11,006
Maize (white)	0	0	0	0	92,652	0	72,112
Poultry (eggs)	0	0	0	1,341	0	0	7,105

Source: Model results.
Note: MT = (Metric tons) S1 = inc. poultry meat import tariff to 45 percent; S2 = doubling production of poultry meat; S3 = increased efficiency in both poultry sectors, lowering feed-conversion rate by 20 percent; S4 = doubling capacity and output of domestic broiler feed and by 20 percent for layer feed; S5 = inc. output of white maize by 20 percent; S6 = accelerating yellow maize production (a 7.7-fold increase in output); S7 = combining simulations S2 through S6.

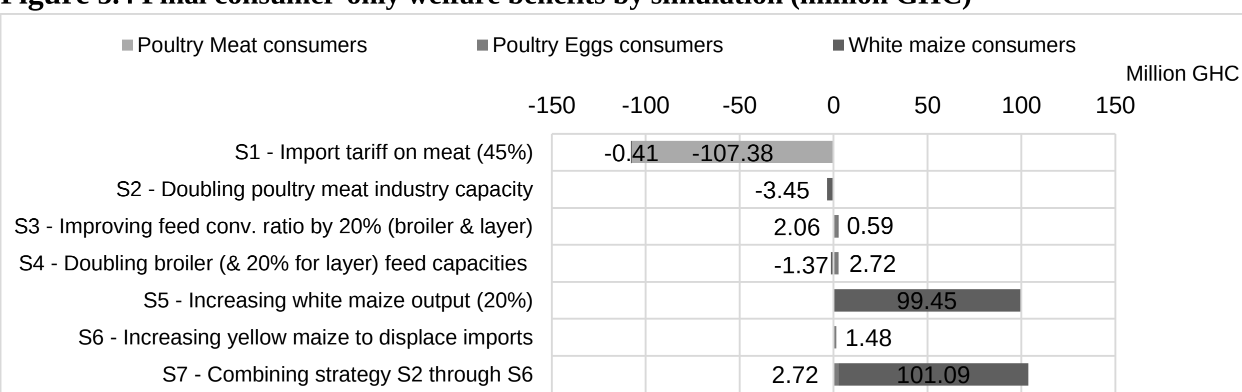
Our measures of producer and consumer surplus use a value chain approach. It was important to represent the net economic "producer" benefits within each sector as inclusive of any consumer benefits derived from an input into production. For example, the poultry meat sector not only benefits from higher chicken meat prices following the rise in import tariffs, but also faces potential losses in consumer surplus as the cost (price) of broiler feed rises with upward pressure on feed demand. However, because the industry is able to import feed inputs, the expected rise in feed prices is dampened. The same can be said of the feed sector. Economic "producer" welfare benefits for this sector stem from the typical change in producer surplus following a change in feed prices. They also do so inclusive of a change in consumer surplus flowing from a change in input prices for feed production (in this case, grain prices; white maize targeted for the feed sector, yellow maize, and soybeans). Therefore, the net economic welfare benefits to producers in Figure 5.3 is net of the producer and consumer surplus measures, depending on the type of commodity linkages (inputs and outputs) involved. In the meantime, therefore, the economic welfare benefits to consumers in Figure 5.4 can be found by measuring the typical consumer surplus among final consumers of white maize, poultry meat, and eggs. Table B.2 in the appendix reports the original measures of producer and consumer surplus by each of the seven commodities.

Figure 5.3 Producer/industry net welfare benefits by simulation (million GHC)



Source: Author calculations based on model results. See Tables B.2 and B.3 in Appendix B for calculations.
Note: S1 = inc. poultry meat import tariff to 45 percent; S2 = doubling production of poultry meat; S3 = increased efficiency in both poultry sectors, lowering feed-conversion rate by 20 percent; S4 = doubling capacity and output of domestic broiler feed and by 20 percent for layer feed; S5 = inc. output of white maize by 20 percent; S6 = accelerating yellow maize production (a 7.7-fold increase in output); S7 = combining simulations S2 through S6.

Figure 5.4 Final consumer-only welfare benefits by simulation (million GHC)



Source: Author calculations based on model results. See Tables B.2 and B.3 in Appendix B for calculations.
Note: S1 = inc. poultry meat import tariff to 45 percent; S2 = doubling production of poultry meat; S3 = increased efficiency in both poultry sectors, lowering feed-conversion rate by 20 percent; S4 = doubling capacity and output of domestic broiler feed and by 20 percent for layer feed; S5 = inc. output of white maize by 20 percent; S6 = accelerating yellow maize production (a 7.7-fold increase in output); S7 = combining simulations S2 through S6.

Returning to the results in Table 5.4, and following the first simulation (S1) from increasing the import tariff for poultry meat to 45 percent, note how demand for broiler feed rises by the same proportion as the increase in production of chicken meat. This is because we explicitly linked the broiler feed sector directly to the poultry meat industry. The effect on the broiler feed price is minimal, nevertheless, because the poultry industry imports feed inputs from neighboring countries. Imports of broiler feed increase by 45 percent in the Brong Ahafo border region, with Côte d'Ivoire as a major supplier of feed. Because the share of white maize used by the broiler feed sector is very small relative to the sector of direct consumers in Ghana, the impact on maize prices is very small (0.1 percent). Despite benefiting domestic meat producers, the net economic producer benefits turn out to be quite small (GHC 7 million, Figure 5.3) relative to the large economic loss among final consumers of poultry meat (losing up to GHC 84.3 million, Figure 5.4).

What if investments were put in place to double the capacity of the domestic poultry meat production industry? This is what we do in the second simulation (S2). Table 5.4 indicates that while we would have expected a similar response to that of feed production—the fact that broiler feed production may be constrained in responding quickly to demand—the poultry meat industry simply imports the additional feed from neighboring countries (especially Côte d'Ivoire). Here imports increase more than 7-fold, from about 4.7 to 35 thousand metric tons. Nevertheless, production of broiler feed expands by 9.8 percent. The increase in imports dampens the price effect on broiler feed as demand increases, rising by only 5.9 percent and a mere 0.3 percent for white maize (a major ingredient in broiler feed). Naturally, the poultry meat industry benefits the most, earning GHC 85 million in net "producer" benefits (Figure 5.3). The main losers are white maize consumers (Figure 5.4), who face a marginal price increase of 0.8 percent.

The third simulation (S3) improves the production efficiencies of both the poultry meat and egg industries by reducing the FCR by 20 percent. Recall that the FCR measures the amount of feed (in metric tons) required to produce one metric ton of poultry meat or poultry eggs. Table 5.4 clearly indicates that this has the effect of reducing demand for feed by 15 percent to 18 percent in the meat and egg industries, respectively. It also shows the corresponding fall in demand for soybeans and yellow maize as key ingredients in layer feed. The decline in feed demand also implies reduced imports for both types of feed. Prices for feed also fall by about 6 percent, all in all benefiting both poultry industries, with production increasing by 5.8 percent for poultry meat and 2 percent for eggs. The effect on net "producer" welfare in both industries remains marginal, yet positive (Figure 5.3). The layer industry experiences higher returns simply due to its scale effect relative to the broiler production sector.

Next, we double the capacity of the broiler feed sector and add 20 percent capacity to the layer feed industry in S4 (the latter already produces a sufficiently large quantity relative to the broiler feed industry). This has the effect of reducing feed prices as supply increases, ultimately benefiting the poultry industry in general. The doubling of capacity for broiler feed leads to a greater supply, increasing meat output by 39.4 percent as prices for feed decline. In the layer feed sector, the increased capacity of 20 percent expands egg production by 7.5 percent as prices for layer feed also decline. The increased comparative advantage for local feed leads to a complete reduction in imports for both feed types. Finally, the economic effects on both the poultry and feed sectors appear to be quite significant, as evident in Figure 5.3. The meat and egg industries witness increases in net "producer" welfare of GHC 35 million and GHC 28 million in value, respectively. Although the increase in capacity for layer feed production was only 20 percent (compared with doubling for broiler feed), the sector accrues the largest benefits due simply to its scale.

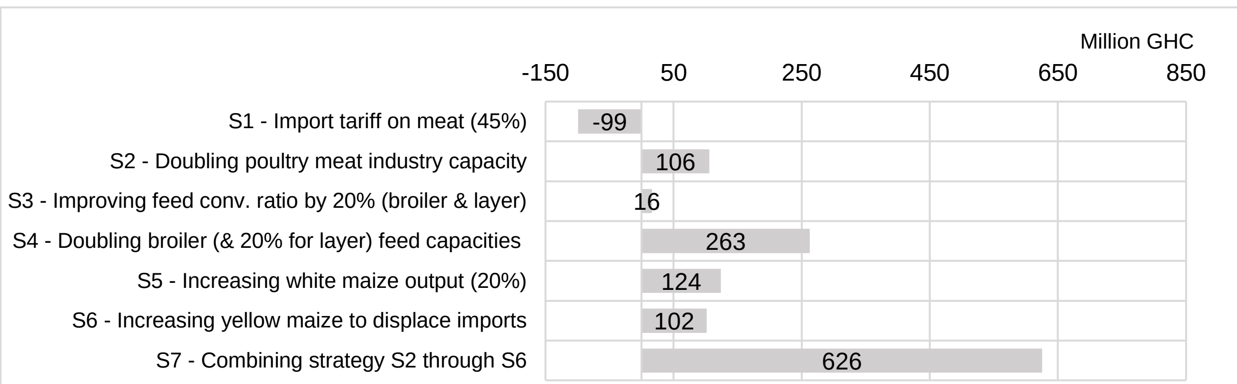
One way to lower input costs for feed production is to lower domestic maize prices. This can be achieved by increasing output by adopting higher-yield varieties and expanding crop area. If we assume investments in the sector can help to lead to a 20 percent increase in national output for white maize (as in the S5 simulation), we would expect this to benefit the broiler feed sector if prices fall. This occurs somewhat, with prices falling on average by 8.8 percent for white maize (Table 5.4). This benefits not only the broiler feed sector—though marginally by GHC 1 million (Figure 5.3)—but maize consumers as well, up to GHC 107 million in consumer surplus (Figure 5.4). Because much of the increase in output can be absorbed from increased exports to neighboring countries (Table 5.4), white maize farmers actually experience large gains—about GHC 18 million in producer surplus (Figure 5.3).

We also consider increasing output for yellow maize as a key ingredient in the production of layer feed. This is one commodity Ghana continues to substantially rely on from imports, even though the country can potentially produce the commodity. In S6, we increase the production output for yellow maize to be just sufficient to displace imports altogether. This turns out to be a 7.7-fold increase.

Finally, combining S2 through S6 as an integrated feed and poultry sector development strategy, both sectors show a remarkable response—more than doubling in output. However, because the share of the poultry market supplied by domestic producers is so small, imports of poultry decline only marginally, by 9.6 percent. The reduced volume of imports turns out to be about equivalent to simply raising the import tariff for poultry meat to 45 percent. However, the net economic effects are drastically different. The tariff reduces consumption of poultry meat, leading to significant losses in consumer welfare. The integrated feed and poultry development strategy (S7), on the other hand, actually increases net economic welfare in both industries, as well as among farmers producing both white and yellow maize. At the same time, maize consumers also benefit, experiencing a consumer surplus of GHC 108.7 million in economic value (Figure 5.4).

Figure 5.5 shows the net welfare benefits. As it turns out, increased output in maize, feed, and poultry actually leads Ghana to become a net exporter into neighboring countries for white maize, both types of feed, and eggs. Clearly, an integrated feed and poultry development strategy also produces the greatest welfare benefits. However, this does not take into account the investment costs that will need to be spent on: (1) increasing poultry production capacities; (2) improving productivity in the poultry sector by lowering the FCR; (3) expanding the feed production sector, especially for broiler feed; and (4) accelerating both white and yellow maize production. As long as these costs are kept below an estimate of GHC 605 million, the benefits can still outweigh the costs.

Figure 5.5 Net economic welfare benefits (producers and consumers) by simulation type (GHC million)



Source: Authors' calculations based on model results.
Note: S1 = increased poultry import tariff from 35 percent to 45 percent; S2 = doubling production capacity for poultry broilers; S3 = increasing efficiency of poultry industry from lowering the feed conversion ratio by 20 percent; S4 = doubling capacity and output of domestic broiler feed sector (20 percent for layer feed sector); S5 = increasing national output of white maize production by 20 percent (due to productivity improvements and area expansion); S6 = accelerating yellow maize production to displace imports (a 7.5-fold increase in output); S7 = feed and poultry investment strategy (combining simulations S2 through S6).

One advantage for investing across the various components of the poultry value chain is that it can produce some additional multiplier effects. We capture this in Table 5.5 by calculating the ratio of benefits under each simulation type relative to S7, the combined strategy. The greatest multiplier effect appears to be in the poultry egg and broiler feed sectors, which experience a 42 percent and an 11 percent increase, respectively, in benefits from the combined strategy because of interaction effects. For the egg industry, this is due mostly to the reduced costs for layer feed (see the price changes in Table 5.4 for both layer feed and lower yellow maize prices). For the broiler feed industry, it is the dramatic expansion in production capacities as well as increased demand as poultry production expands. One important result and a key message of this study is that the resulting domestic expansion in poultry production cannot be expected to make a big dent on imports. At the most, it has the potential to reduce imports by 10 percent if we consider the integrated feed and poultry development strategy. Yet, it is more beneficial to the economy than simply adding tariff walls.

Table 5.5 Multiplier effect of integrated strategy, combining S2 through S6

	Ratio of benefits from individual simulation / relative to combined strategy (S7) benefits							
	S2/S7	**S3/S7**	**S4/S7**	**S5/S7**	**S6/S7**	***Total****	***Multiplier effect***	
Subsector/Industry	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	***100% (S7/S7) - (6)***	
Poultry industry - Broiler	70%	2%	28%	1%	0%	*102%*	-1.5%	**-**
Poultry industry - Layers	0%	12%	34%	0%	10%	*57%*	43.3%	**+++**
Feed industry - Broiler	0%	0%	87%	2%	0%	*89%*	10.7%	**++**
Feed industry - Layers	0%	0%	105%	0%	5%	*110%*	-10.3%	**--**
White maize Farmers	3%	-1%	1%	100%	0%	*104%*	-4.1%	**-**
Yellow maize farmers	0%	0%	0%	1%	113%	*114%*	-14.3%	**--**
Net - Poultry value chain	24%	3%	59%	5%	3%	*94%*	5.6%	**+**

Source: Authors' calculations based on model result of economic surplus welfare measures.
Note: ***This is the sum of (1) through (5). S1 = increased poultry import tariff from 35 percent to 45 percent; S2 = doubling production capacity for poultry broilers; S3 = increasing efficiency of poultry industry from lowering the feed conversion ratio by 20 percent; S4 = doubling capacity and output of domestic broiler feed sector (20 percent for layer feed sector); S5 = increasing national output of white maize production by 20 percent (due to productivity improvements and area expansion); S6 = accelerating yellow maize production to displace imports (a 7.5-fold increase in output); S7 = feed and poultry investment strategy (combining simulations S2 through S6).

6. SUMMARY AND IMPLICATIONS

This study sought to contribute to Ghanaian policy makers' information on the connections between the maize and poultry sectors. Three approaches were used: (1) a review of the available data on the two sectors; (2) a detailed field assessment of the feed milling sector, which is the main link between the two sectors; and (3) a model of outcomes that would result from potential policy actions. The study is set in the context of current policy debates, in which the poultry industry is viewed as an integral part of Ghana's agricultural transformation strategy and there is recognition of the need for more research evidence. While there is a clear recognition among policy makers of value chain linkages across a number of commodity, feed, and poultry production subsectors that make up the industry, there has been very little information available. This study helps to fill that gap.

Among the key findings are those of the field assessment, which confirm two important facts about the poultry feed milling sector in Ghana. First, commercial feed milling has not grown as a stand-alone commercial sector supporting the poultry industry. Although there were more than 15 commercial mills in the country as recently as 10 years ago, there are now only six in operation. The sector is dominated by one firm, and all three remaining medium-sized firms are operating under capacity. Importantly, there is only one firm located in the middle-belt of the country, where the bulk of maize and poultry is produced. This constitutes a shift away from stand-alone or specialized commercial milling enterprises in the feed milling sector. In its place is the emergence of vertically integrated poultry farms with their own feed milling capacity. For smaller-scale poultry farmers, smaller service mills have become a preferred choice for feed. We find some evidence that compared to smaller service mills, the large vertically integrated mills and stand-alone commercial mills are subject to more regulation, use more advanced production technology, and aim for higher standards of feed quality. For the majority of small-scale poultry farmers, the shift away from reliance on larger commercial feed mills to service mills has had adverse impacts on feed quality and, therefore, held back the development of the poultry sector in Ghana more generally. One the other hand, the shift to vertically integrate feed milling with poultry production among larger poultry producers is a positive sign: it helps to reduce costs and allow farmers to become more competitive as their scale of production increases. In general, the poultry production industry enjoys scale economies in farm size, as well as the tendency to integrate vertically (Martinez 2002; Bamiro, Philip, and Momoh 2006).

Second, the findings emphasize the heavy reliance on imports for the two primary commodities in feed production, maize, and soybeans, as well as for specialized ingredients and additives required to enhance growth and improve the nutritional value of feed. There are currently no viable substitutes for these two commodities, although cassava has been considered as an alternative (Oppong-Apane 2013). Nevertheless, there is no reason why Ghana cannot tap into its potential to supply the domestic feed industry with locally sourced maize and soybeans, as both are cultivated locally. As our results showed, increasing the productivity of white maize triggers lower maize prices in the broiler poultry sector, with output growing by about 2.1 percent. The principal challenge is ensuring supply throughout the year when the sector is characterized by rain-fed smallholder agriculture. This was cited by feed millers as one of the principal reasons for the unreliability of local supplies and, therefore, the preference to import.

To displace imports with local grains, various policy and investment options need to be considered to help ensure supply year-round. Among these are (1) improved seeds and technologies at the farm level to increase productivity and output; (2) enhanced post-harvest handling practices to improve quality; (3) expanded irrigation to ensure year-round production; (4) increased capacity for aggregation of smallholder output and grain storage; and (5) upgraded roads and transportation more generally. The ability of Ghana to stimulate productivity-enhanced growth in grains from these investments will not only enable the feed sector to access more of the commodity locally, but to do so at a lower price. That is, 8 percent to 11 percent lower for domestic white and yellow maize, respectively, based on our simulation example. The benefits can be quite large. These investments would benefit not only the feed and poultry sectors, but also smallholder farmers and the millions of direct consumers of maize.

Aside from increasing the supply of domestic grains, feed additives with the potential to be procured locally—such as salt, palm kernel cake, and fish meal—will also require improvements in supply and quality. Many of the feed millers interviewed expressed that finding local alternative feed additives with sufficient quality is a problem. Reducing the operating costs of feed production would also help. For example, the cost and quality of energy supply is constraining mechanized operations, and our field findings show that this is a significant issue for feed millers. Therefore, certain policy actions would also be required to address energy needs, as well as other infrastructure improvements to reduce haulage costs. However, given the number of additives used in the feed sector, most are likely to remain dependent on imports for some time to come. Since additives make up a small share of total production costs (about 20 percent to 25 percent), there is little reason to believe that this is as serious a concern as grain imports.

Finally, dependence on imports for poultry meat is considered by poultry farmers' advocates and policy makers as the most challenging issue facing the domestic sector. Also of concern is the poultry industry's lack of competitiveness. Both these issues focus attention on the large volume of frozen meat imports. However, this study's findings emphasize why it is futile to reverse this trend given the enormity in the volume of imports to satisfy domestic demand. More specifically, we showed how raising import tariffs to reduce imports would make only a small dent in reducing imports. In fact, for Ghana to be self-sufficient in poultry meat production, it would require an almost 20-fold increase in domestic capacity and output. Moreover, it would require the feed and grain sectors to be well positioned to respond quickly to meet demand from the poultry meat sector. This outcome is hardly likely, given the current low productivity and capacity levels in both sectors. Therefore, raising import tariffs will be likely to hurt consumers the most, as they will be forced to pay higher prices for chicken meat. Other researchers have reached similar conclusions about the future of Ghana's poultry industry (Sumberg et al. 2013; Hollinger and Staatz 2015). Rather, there may be room to explore how the small domestic poultry meat industry can focus more attention on differentiating its product from imported brands. After all, local chicken is often preferred by consumers, who often express a willingness to pay a price premium for it (Hollinger and Staatz 2015). More research is needed to determine whether such product differentiation in branding and marketing is a viable option.

Compared to the meat part of the poultry industry, the egg-producing sector is much larger and is currently able to meet the country's consumption needs. Growing the egg industry further, therefore, may offer the potential for Ghana to become an exporter to neighboring countries over the long run. To improve the industry, our findings suggest that a policy that focuses on increasing the supply of yellow maize in Ghana would have significant benefits for both the feed and egg industries. This would make feed production for layers, as well as egg production, more cost-effective. In addition, it would generate an alternative source of income for those farmers who choose to grow the yellow maize demanded by the egg industry. However, for yellow maize to be attractive to farmers, production will have to be sufficiently profitable relative to white maize, and competitive against imports of yellow maize.

In summary, the difficulties that have been highlighted for sourcing local suppliers of inputs for the feed industry in particular have important implications on the entire poultry value chain. First, given the constraints at the primary commodity level, it would take more than a mere expansion in poultry production for it to serve as a primary source of demand for locally produced feed ingredients. Instead, this study has shown that a policy that takes on an integrated approach of improving the entire poultry value chain offers a win-win strategy. This means focusing attention on improving all three sectors in the value chain (grains, feed, and, finally, poultry production). Not only would such a policy benefit the feed and poultry sectors directly, it would also help farmers and consumers alike. In fact, with an integrated poultry development strategy in place, Ghana has the potential to eventually become a net exporter of maize, poultry feed, and eggs to neighboring countries.

APPENDIX A: DESCRIPTION OF THE SPATIAL EQUILIBRIUM MODEL OF THE POULTRY AND FEED SECTORS

We assess how changes in intraregional trade flow of feed (and its commodity components, maize and soybeans) and poultry within Ghana will occur. Also explored are the associated welfare implications resulting from changes in global and domestic markets. To accomplish this, we use a spatial equilibrium model in the tradition of Takayama and Judge (1964), Harker (1986), and others. These models were originally cast as simple transportation problems. They were solved using linear programming optimization routines. These routines involved minimizing transportation costs between regions, given prices and excess supply and demand, or maximizing social welfare (net producer and consumer surplus) subject to transportation cost and the usual supply and demand constraints. Later, however, the models were easily translated into a complementary problem when the use of linear or nonlinear programming approaches proved less efficient (Rutherford 1995; Arndt, Schiller, and Tarp 2001).

Mathematically, a generalized form of the spatial equilibrium problem is typically solved as a nonlinear optimization problem that maximizes net social welfare subject to transportation costs, a world price for imports, and local supply and demand constraints. Net social welfare benefits are measured as the integrals of the inverse demand and supply functions.[17] By taking the first-order conditions and using the Kuhn Tucker Conditions for a local maximum, the problem can be converted into its complementarity expression as a system of relational inequalities and complementarity variables.

Using this general specification of the complementarity problem, a four-commodity spatial equilibrium model is developed for Ghana to simulate seven distinctive commodities in eight regions.[18] The commodities are white maize, yellow maize, soybeans, broiler feed, layer feed, poultry meat, and poultry eggs. Maize and soybeans serve as primary commodity inputs of feed, which, in turn, is an intermediate commodity for producing poultry. Among the seven commodities, we assume feed cannot be imported from global markets but only from the adjacent neighboring countries of Côte d'Ivoire, Togo, and Burkina Faso in the north. While obtaining data to confirm this is difficult, we assumed borders are porous enough to allow for trade in the wider West Africa region. Maize, soybeans, and poultry eggs can also be traded in the region—restricting poultry meat to imports from global markets only.

Trade for each commodity among the eight regions in Ghana occurs when the price difference between them reaches the full cost of transporting the commodity among the regions. Similarly, the commodities are imported when the wholesale price in a region rises as high as the import parity price for that region; they are exported when it falls as low as the region's export parity price. For the four commodities imported from global markets (both maize types, soybeans, and poultry meat), we consider Ghana a "small country" importer that cannot influence the world price. In other words, the world price is considered fixed. While imports to Ghana from global markets enter through Accra only (that is, via the port of Tema), we allow some overland trade via Ivory Coast and Togo global ports for soybeans and maize (based on interviews in the field).

Mathematically, the model can be described as follows. Assuming quadratic demand and supply functions: (Q_{kj}^{d}) in a region j and (Q_{ki}^{s}) for region i ($i = 1 \ldots 6$) for commodity k ($k = m, s, f, c$, where m = maize, m = soybeans, f = poultry feed, and m = chicken meat or poultry), and allowing for some limited cross-price effects, these and their complementarity variables are represented in the model as:

Demand for poultry:

$$Q_{cj}^{d}(P_{cj}) = \alpha_{cj} - \sum_k \beta_{kj} P_{kj}\,, \;\perp\; Q_{cj}^{d} \geq 0 \quad \forall j \in N; \forall k \tag{1}$$

[17] This is really the net of consumer and producer surplus.
[18] We aggregated the northern region to include Upper West and Upper East.

Demand for maize (includes maize demanded for feed production):

$$Q_{mj}^{d}(P_{mj}) = \alpha_{mj} - \sum_{k} \beta_{kj} P_{kj} + 0.7(Q_{fj}^{s}),\ \perp\ Q_{fj}^{d} \geq 0 \quad \forall j \in N, \forall k \tag{2}$$

Demand for soybeans (exclusively demanded for feed production only):

$$Q_{sj}^{d}(P_{sj}) = 0.3(Q_{fj}^{s}),\ \perp\ Q_{sj}^{d} \geq 0 \quad \forall j \in N \tag{3}$$

Demand for feed (as a derived demand from chicken meat production function):[19]

$$Q_{fj}^{d}(P_{fj}) = g(Q_{cj}^{s}),\ \perp\ Q_{fj}^{d} \geq 0 \quad \forall j \in N \tag{4}$$

On the supply side, we restrict all soybeans to imports, while for maize, feed, and chicken meat, it follows:

$$Q_{ki}^{s}(P_{ki}) = \gamma_{ki} + \sum_{l} \delta_{li} P_{li}\,,\ \perp\ Q_{ki}^{s} \geq 0 \quad \forall i \in N, \forall k = m, f, c; \forall l \tag{5}$$

$$Q_{si}^{s}(P_{si}) = 0,\ \perp\ Q_{si}^{s} \geq 0 \quad \forall i \in N \tag{6}$$

where k in both equations (1), (2), and (5) allows for cross-price effects, α_{kj} and γ_{ki} are intercepts, and β_{kj} and δ_{ki}, are slope parameters for demand and supply curves of commodity, with $\beta_{kj} < 0$ and $\delta_{ki} > 0$. Equilibrium conditions for excess supply and demand determine the equilibrium prices of each commodity within each region, as follows:[20]

For maize and feed (as these can be exported to the West African region):

$$Q_{ki}^{d} = Q_{ki}^{s} + M_{ki} - X_{ki} + \sum_{i=1}^{N} \sum_{j=1}^{N} (Z_{kji} - Z_{kij})\,,\ \perp\ P_{ki} \geq 0, \quad \forall ij \in N, \forall k = m, f \tag{7}$$

For soybeans and chicken meat (imported from global markets):

$$Q_{ki}^{d} = Q_{ki}^{s} + M_{ki} + \sum_{i=1}^{N} \sum_{j=1}^{N} (Z_{kji} - Z_{kij})\,,\ \perp\ P_{ki} \geq 0, \quad \forall ij \in N, \forall k = s, c \tag{8}$$

The variable Z_{kij} represents trade flows between regions for each commodity, i.e. the quantities of commodity k that is transported between a supply region i and a demand region j, while M_{ki} and X_{ki} represents exports and imports to/from global or West Africa. Trade flows in Z_{kij} are constrained as positive, i.e. commodity k can only be transported in one direction at each given time. Both $X_{kij}$and M_{ki} are determined separately by the price relationships in equations (9) through (12) below, respectively.

As market equilibrium conditions, equations (7) and (8) expresses the requirement that supply quantities of each commodity between regions has to equal the quantity demanded in the region receiving the commodity. Similarly, the quantity shipped out by a region cannot be more than what is available in the region to ship, less any quantities demanded locally. Both equations determine the equilibrium prices for each commodity type (P_{kj}) respectively.

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[19] The production function is a simple conversion factor based on interviews with feed millers and adjusted by a factor of 1.3 for model calibration purposes. The final conversion factor used is: $g(Q_{cj}^{s}) = \frac{1.3(3.5)}{1.2}$.

[20] This is really combining equations (1) and (2) from the more general specification of the spatial equilibrium model.

Now, given transportation and marketing costs, c_{ij} (again using the same notation as in the general case for either commodity), we can now determine the trade flows (Z_{kij}) between regions. As the complementarity variable here, it is determined by the price differential between regions, inclusive of transportation and marketing costs (c_{ij}):

$$P_{ki} + c_{ij} = P_{kj}, \perp \; Z_{kij} \geq 0 \tag{9}$$

Furthermore, since we have added the option for importing maize, soybeans, and chicken meat from global, and we wish to add an import tariff (τ_i), we can express this price relationship as follows:

$$\bar{p}^{w}_{ki^e}(1 + \tau_{i^e}) \geq P_{ki^e}, \perp \; M_{ki} \geq 0 \qquad \forall i^e = Accra; \; \forall k = m, s, c \tag{10}$$

For imports from West African regional markets, and since we restricted this to maize and feed only, this is expressed as:

$$\bar{p}^{w}_{ki^e}(1 + \tau_{i^e}) \geq P_{ki^e}, \perp \; M_{ki} \geq 0 \qquad \forall i^e \neq Accra; \; \forall k = m, f \tag{11}$$

Similarly, allowing for exports to the West African region for maize and feed only, and adding an export tax (t_i), we have:

$$P_{ki^e} \geq \bar{p}^{w}_{ki^e}(1 + t_{i^e}), \perp \; X_{ki} \geq 0 \qquad \forall i^e \neq Accra; \; \forall k = m, f \tag{12}$$

The $\bar{p}^{w}_{i^a}$ in equations (10) through (12) represent the world (or West Africa regional) price at the port of entry or exit, including any port handling charges and fees. This is prior to adding any costs of an import tariff or export tax.

Finally, in simultaneously solving for the sequence of equations and complementarity relationships in equations (1) through (12), an optimal solution in the variables, $Q^d_{kj}, Q^s_{ki}, Z_{ijk}, M_{ki}$ and X_{ki} (including equilibrium prices, P_{ki}) can be determined. Results are aggregated across the eight regions in Ghana.

APPENDIX B: SUPPLEMENTARY TABLES

Table B.1 Assumed own and cross-price elasticities

Own price elasticity of demand						
	Broiler feed	**Layer feed**	**White maize**	**Yellow maize**	**Poultry meat**	**Poultry eggs**
Own price elasticity of demand	-	-	-0.47	-0.40	-0.80	-0.64
Own and cross-price elasticity of supply						
Broiler feed	0.50	0.00	-0.50	0.00	0.80	0.00
Layer feed	0.00	0.50	0.00	-0.50	0.00	0.50
White maize	0.00	0.00	0.45	0.00	0.00	0.00
Yellow maize	0.00	0.00	-0.50	0.40	0.00	0.00
Poultry meat	-0.80	0.00	0.00	0.00	0.50	0.00
Poultry eggs	0.00	-0.80	0.00	0.00	0.00	0.50

Source: Alene et al. (2009) and Byerlee and Traxler (1995).

Table B.2 Producer and consumer welfare by commodity: All seven commodities, GHC million

Commodity	S1	S2	S3	S4	S5	S6	S7
Producer surplus							
Broiler feed (a)*	138	228	-138	51,676	166	0	59,438
Layer feed (b)	0	0	0	137,863	0	0	114,597
Soybeans (c)							
White maize (d)	80	675	-116	270	19,299	0	19,335
Yellow maize (e)	-5	-45	-107	-18	1,117	85,898	75,990
Poultry meat (f)	8,526	111,474	2,079	21,421	1,138	0	132,367
Poultry eggs (g)							
Consumer surplus							
Broiler feed (h)	-17	-3,257	1,679	22,274	1,007	0	23,112
Layer feed (i)	0	0	9,018	23,160	81	7,212	62,417
Soybeans (j)	0	0	0	0	0	0	0
White maize (k)	-422	-3,554	600	-1,400	100,713	0	101,089
Yellow maize (l)	0	0	67	0	72	6,262	16,243
Poultry meat (m)	-107,382	0	0	0	0	0	0
Poultry eggs (n)	0	0	2,063	2,716	18	1,481	2,716
Total							
Broiler feed	120	-3,029	1,540	73,950	1,173	0	82,550
Layer feed	0	0	9,018	161,023	81	7,212	177,013
Soybeans	0	0	0	0	0	0	0
White maize	-341	-2,879	484	-1,130	120,013	0	120,424
Yellow maize	-5	-45	-41	-18	1,189	92,160	92,233
Poultry meat	-98,856	111,474	2,079	21,421	1,138	0	132,367
Poultry eggs	0	0	3,084	7,257	27	2,224	21,031

Source: Model results.
Note: *The letters in brackets are used as reference points for calculating the net "producer" welfare benefits by sector/industry as presented in Table B3 below.

Table B.3 Net "producer" economic welfare by industry/sector and final consumer welfare, GHC million

Commodity	S1	S2	S3	S4	S5	S6	S7
Producer surplus							
Poultry meat industry (f + h)[a]	8.51	108.22	3.76	43.70	2.15	0.00	155.48
Poultry egg industry (g + i)	0.00	0.00	10.04	27.70	0.09	7.95	80.73
Broiler feed producers (a + θ*k)[b]	0.13	0.13	-0.13	51.65	1.43	0.00	59.44
Layer feed producers (b + l)	0.00	0.00	0.07	137.86	0.07	6.26	130.84
White maize farmers (d)	0.08	0.68	-0.12	0.27	19.30	0.00	19.34
Yellow maize farmers (e)	-0.01	-0.05	-0.11	-0.02	1.12	85.90	75.99
Total (1)	*8.72*	*109.02*	*13.62*	*261.18*	*23.03*	*14.22*	*445.82*
Final consumer surplus							
Poultry meat consumers (m)	-107.38	0.00	0.00	0.00	0.00	0.00	0.00
Poultry eggs consumers (n)	0.00	0.00	2.06	2.72	0.02	1.48	2.72
White maize consumers ((1- θ)*k)	-0.41	-3.45	0.59	-1.37	99.45	0.00	101.09
Total (2)	*-107.80*	*-3.45*	*2.66*	*1.34*	*99.47*	*1.48*	*103.80*
Net welfare (1 + 2)	*-99.08*	*105.57*	*16.27*	*262.52*	*122.50*	*15.70*	*549.63*

Source: Model results.
Note: [a] The letters in brackets are referenced from Table B.2. [b] Here θ is the share of white maize demanded by the broiler feed sector versus the share demanded directly by consumers.

Table B.4 Interregional trade flows (Metric tons)

From	To	Simulations							
		Base	S1	S2	S3	S4	S5	S6	S7
Feed (broiler)									
Accra	Ashanti	2,230	1,963		2,749		3,165	2,230	4,257
Accra	Brong Ahafo								1,121
Accra	Central	80	165					80	
Accra	Eastern	268	404		53		107	268	
Accra	Volta		18			10,401			2,600
Accra	Western		20						
Ashanti	Brong Ahafo								71
Ashanti	Central			9					
Ashanti	Western			8					
Brong Ahafo	Ashanti	1,896	3,014	17,568				1,896	
Brong Ahafo	Central			1,208					
Brong Ahafo	Western			346					
Central	Ashanti					498			133
Eastern	Ashanti								175
Eastern	Volta					1,086			
Volta	Accra			676					
Volta	Eastern			2,127					
Western	Ashanti					132			3
Western	Brong Ahafo								5
Ashanti	Brong Ahafo					274			3,151
Brong Ahafo	Ashanti	3,876	3,876	3,876			3,867		
Central	Accra								603
Eastern	Accra								736
Eastern	Ashanti				236	431		588	
Eastern	Brong Ahafo					88			
Eastern	Volta								1,807
Northern	Ashanti						3		
Northern	Brong Ahafo				508	591		1,206	1,587
Volta	Accra	3,331	3,331	3,331	2,399	3,145	3,330	5,030	
Volta	Ashanti				384	754		486	
Volta	Brong Ahafo					6			

Table B.4 Continued

		Simulations							
From	**To**	**Base**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
Feed (broiler)									
Volta	Eastern	986	986	986	890	1,065	986	620	
Western	Accra								359
Western	Ashanti							14	
Western	Central					2			32
Soybeans									
Accra	Ashanti	19,335	19,524	19,314	17,825	24,952	19,933	20,703	25,923
Accra	Brong Ahafo	13,266	13,422	13,246	12,411	18,660	13,472	12,993	17,659
Accra	Central	2,838	2,870	2,911	2,583	3,305	2,872	2,951	3,491
Accra	Eastern	5,297	5,364	5,445	4,554	6,699	5,364	5,748	7,347
Accra	Volta	3,590	3,618	3,610	3,169	4,509	3,636	4,552	5,928
Accra	Western	567	590	616	328	937	588	676	1,077
Ashanti	Brong Ahafo	537	504	538	1,193	927	758	665	951
Central	Western	916	906	892	932	819	903	912	773
Volta	Northern	1,084	1,095	1,092	1,041	1,494	1,120	1,463	1,806
Maize (white)									
Ashanti	Accra						11,243		6,314
Ashanti	Central				1,278	537		2,255	
Ashanti	Western	28,796	28,560	27,353	28,662	27,882	19,872	28,045	18,969
Brong Ahafo	Accra						16,269		7,316
Brong Ahafo	Ashanti	211,461	211,754	212,788	212,034	212,656	237,699	212,964	239,814
Brong Ahafo	Central	5,010	4,864	3,510	4,034	3,914		2,755	
Brong Ahafo	Western	79,908	79,965	79,792	80,347	80,189	97,222	80,660	98,435
Eastern	Accra	155,647	155,702	156,602	155,575	155,804	230,498	155,647	228,887
Northern	Ashanti			1,690					
Northern	Central			0					
Northern	Volta	247,642	248,026	248,945	247,214	248,620	186,154	247,642	206,287
Volta	Accra	160,605	161,069	162,583	160,080	161,793	97,321	160,605	117,061

Table B.4 Continued

From	To	Base	S1	S2	S3	S4	S5	S6	S7
		Simulations							
Maize (yellow)									
Accra	Ashanti	38,582	38,584	38,597	31,754	42,606	38,246		
Accra	Central	2,639	2,640	2,648	2,125	3,033	2,384		
Accra	Eastern	6,372	6,374	6,391	4,547	7,685	5,733		
Accra	Volta	1,311	1,311	1,315	940	1,601	1,161		
Accra	Western	1,749	1,749	1,754	1,250	2,137	1,621		
Ashanti	Brong Ahafo							19	250
Brong Ahafo	Northern	250	251	263		347			
Central	Ashanti							9,195	9,090
Central	Western	1,416	1,415	1,411	1,431	1,410	1,543	3,400	3,414
Eastern	Accra							6,431	5,908
Eastern	Ashanti							17,816	18,870
Eastern	Brong Ahafo							1,210	189
Northern	Brong Ahafo							11,943	12,030
Volta	Accra							5,539	5,683
Poultry (meat)									
Accra	Ashanti	47,012		42,067	46,779	45,214	46,896	47,013	41,242
Accra	Brong Ahafo	18,090		14,449	18,096	16,669	18,093	18,089	12,722
Accra	Central	14,488	13,156	14,074	14,460	14,278	14,466	14,488	13,834
Accra	Eastern	16,471	14,729	15,600	16,423	16,096	16,447	16,471	15,135
Accra	Volta	23,991		23,499	23,951	23,810	23,958	23,991	23,300
Accra	Western	16,537	15,049	16,249	16,516	16,389	16,521	16,537	16,082
Ashanti	Brong Ahafo	6				138	2	6	828
Brong Ahafo	Ashanti		42,191						
Central	Western	2,785	2,630	2,912	2,793	2,848	2,792	2,785	2,985
Volta	Northern	9,213		8,961	9,193	9,119	9,193	9,213	8,859

Table B.4 Continued

From	To	Simulations							
		Base	S1	S2	S3	S4	S5	S6	S7
Poultry (eggs)									
Ashanti	Accra	2,942	2,942	2,942	2,964	2,704	2,942	2,960	1,408
Ashanti	Central	186	186	186	247	133	185	207	5
Ashanti	Volta	1,324	1,324	1,324	1,328	2,637	1,325	1,329	8,370
Ashanti	Western	542	542	542	608	494	541	570	5
Brong Ahafo	Accra	3,848	3,848	3,848	3,751	3,685	3,851	3,792	3,999
Brong Ahafo	Ashanti	1,179	1,179	1,179	1,059	1,254	1,182	1,105	2,864
Brong Ahafo	Central	1,314	1,314	1,314	1,256	1,336	1,316	1,261	1,256
Brong Ahafo	Northern	767	767	767	788	779	755	776	655
Brong Ahafo	Western	1,623	1,623	1,623	1,569	1,650	1,625	1,576	1,942
Eastern	Accra	628	628	628	734	919	627	697	1,462

Source: Model results.

REFERENCES

Alene, A. D., A. Menkir, S. O. Ajala, B. Badu-Apraku, A. S. Olanrewaju, V. M. Manyong, and A. Ndiaye. 2009. "The Economic and Poverty Impacts of Maize Research in West and Central Africa." *Agricultural Economics* 40 (5): 535–550.

Angelucci, F. 2012. *Analysis of Incentives and Disincentives for Maize in Ghana.* Monitoring African Food and Agricultural Policies (MAFAP). Rome: Food and Agriculture Organisation of the United Nations (FAO).

Aning, K. G. 2006. *The Structure and Importance of the Commercial and Village Based Poultry in Ghana.* Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/docs/eims/upload/213723/agal_poultryreview_ghana_aug06.pdf.

Arndt, C., R. Schiller, and F. Tarp. 2001. "Grain Transport and Rural Credit in Mozambique: Solving the Space-Time Problem." *Agricultural Economics* 25: 59–70.

Bamiro, M. O., A. O. D. Philip, and S. Momoh. 2006. "Vertical Integration and Technical Efficiency in Poultry (Egg) Industry in Ogun and Oyo States, Nigeria." *International Journal of Poultry Science* 5 (12): 1164–1171.

Birol, E., and D. Asare-Marfo. 2008. *Impact of Highly Pathogenic Avian Influenza on Ghanaian Rural Chicken Producers' Incomes*. Highly Pathogenic Avian Influenza Research Brief 1. Incomes', Africa/Indonesia Team Working Paper, (16). London: Department for International Development.

Byerlee, D., and G. Traxler. 1995. "National and International Wheat Improvement Research in the Post-Green Revolution Period: Evolution and Impacts." *American Journal Agricultural Economics* 77 (2): 268–78.

Chisenga, J., C. Entsua-Mensah, and J. Sam. 2007. "Impact of Globalization on the Information Needs of Farmers in Ghana: A Case Study of Small-Scale Poultry Farmers." In *World Library and Information Congress: 73rd General Conference and Council.* Durban, South Africa: International Federation of Library Associations.

Davis, G. C., D. Harvey, S. Zahniser, F. Gale, and W. Liefert. 2013. "Assessing the Growth of U.S. Broiler and Poultry Meat Exports." Livestock, Dairy, and Poultry Outlook No. LDPM-231-01. Washington, DC: United States Department of Agriculture - Economic Research Service. http://www.ers.usda.gov/media/1217411/ldpm-231-01-with-keywords.pdf.

Diao, X. 2008. *Impact of Highly Pathogenic Avian Influenza on the Ghanaian Economy.* Africa/Indonesia Team Working Paper 3. London: Department for International Development. http://www.hpai-research.net.

FAO (Food and Agriculture Organization of the United Nations). 2003. "Egg Marketing - A Guide for the Production and Sale of Eggs. *FAO Agricultural Services Bulletin 150.* Rome.

———. 2010. "Commodity Balances, Livestock and Fish, Primary Equivalent." FAO Statistical Database. Rome. http://faostat.fao.org/default.aspx

———. 2014. "Poultry Sector Ghana." *FAO Animal Production and Health Livestock Country Review*. 6: 1–81. Rome. http://www.fao.org/ag/againfo/themes/en/poultry/home.html.

———. 2015. "Commodity Balances, Livestock and Fish, Primary Equivalent." *FAO Statistical Databases*. Rome. https://knoema.com/FAOCBLSF2015/commodity-balances-livestock-and-fish-primary-equivalent-1961-2013?location=1000670-ghana.

Harker, P. T. 1986. "Alternative Models of Spatial Competition." *Institute of Operations Research and the Management Sciences* 34 (3): 410–425.

Hellin, J., O. Erenstein, and K. Pixley. 2010. "Maize-Poultry Value Chains and Quality Protein Maize in India: Implications for Research and Development." In *Maize for Asia: Emerging Trends and Technologies. Proceeding of The 10th Asian Regional Maize Workshop*, edited by P. H. Zaidi, M. Azrai, and K. V.Pixley, 585–588. Mexico City: International Maize and Wheat Improvement Center (CIMMYT).

Hellin, J., V. V. Krishna, O. Erenstein., and C. Boeberd. 2015. "India's Poultry Revolution: Implications for Its Sustenance and the Global Poultry Trade." *International Food and Agribusiness Management Review* 18 (Special Issue A): 151–64. http://www.ifama.org/files/IFAMR/Volume 18/Special Issue A/2014013411.pdf.

Hollinger, F., and J. M. Staatz. 2015. *Agricultural Growth in West Africa: Market and Policy Drivers*. Rome: Food and Agriculture Organization of the United Nations and African Development Bank. http://www.fao.org/3/a-i4337e.pdf.

Killebrew, K., and R. Plotnick. 2010. *Poultry Market in West Africa: Ghana.* EPAR Brief No. 83. Seattle, WA, US: Evans School Policy Analysis and Research, University of Washington.

Martinez, Steve W. 2002. *Vertical Coordination of Marketing Systems: Lessons from the Poultry, Egg, and Pork Industries.* Agricultural Economic Report No. 807. Washington DC: United States Department of Agriculture - Economic Research Service.

Mensah-Bonsu, A., and K. M. Rich. 2010. *Ghana's Poultry Sector Value Chains and the Impacts of Highly Pathogenic Avian Influenza*. Pro-Poor Highly Pathogenic Avian Influenza (HPAI) Risk Reduction Project Working Paper No. 26. Nairobi: International Livestock Research Institute.

MoFA (Ministry of Food and Agriculture). 2010. *Agriculture in Ghana: Facts and Figures (2010).* Statistics, Research and Information Directorate. Accra, Ghana. http://mofa.gov.gh/site/wp-content/uploads/ 2011/10/Agriculture-in-Ghana-FF-2010.pdf.

Oppong-Apane, K. 2013. *Cassava as Animal Feed in Ghana: Past, Present and Future*. Accra, Ghana: Food and Agriculture Organization of the United Nations. http://www.fao.org/docrep/018/i3304e/i3304e.pdf.

Ragasa, C., A. Dankyi, P. Acheampong, A. N. Wiredu, A. Chapoto, and R. Tripp. 2013. *Patterns of Adoption of Improved Maize Technologies in Ghana.* Ghana Strategy Support Program Working Paper 36. Accra, Ghana: International Food Policy Research Institute.

Ravindran, V. 2013. "Poultry Feed Availability and Nutrition in Developing Countries: Main Ingredients Used in Poultry Feed Formulation." *Poultry Development Review* 2: 60-63.

Rutherford, T. F. 1995. "Extension of GAMS for Complementarity Problems Arising in Applied Economic Analysis." *Journal of Economic Dynamics and Control* 19 (8): 1299–1324.

Shiferaw, B., B. M. Prasanna, J. Hellin, and M. Bänziger. 2011. "Crops That Feed the World 6. Past Successes and Future Challenges to the Role Played by Maize in Global Food Security." *Food Security* 3: 307–27.

Sumberg, J., M. Awo, D-D. D. Fiankor, G. T-M. Kwadzo, and J. Thompson. 2013. *Ghana's Poultry Sector: Limited Data, Conflicting Narratives, Competing Visions.* Social, Technological and Environmental Pathways to Sustainability (STEPS) Working Paper 56. Brighton, UK: STEPS Centre.

Takayama T., and G. G. Judge. 1964. "Equilibrium Among Spatially Separated Markets : A Reformulation." *Econometrica Journal of the Econometric Society* 32 (4): 510–24.

Tripp, R., and C. Ragasa. 2015. *Hybrid Maize Seed Supply in Ghana.* Ghana Strategy Support Program Working Paper 40. Accra, Ghana: International Food Policy Research Institute.

United Nations. 2013. UN Commodity Trade Statistics Database; Global Poultry Trends 2013. Accessed on August 23, 2016. http://www.thepoultrysite.com/articles/2972/global-poultry-trends-2013-chicken-imports-rise-to-africa-stable-in-oceania/.

USDA (United States Department of Agriculture). 2011. *Poultry and Products Brief Annual.* Accra, Ghana.

———. 2013. *Ghana Poultry Report Annual.*Accra, Ghana: (United States Department of Agriculture).

van Horne, P. L. M. 2014. *Competitiveness of the EU Egg Sector; International Comparison Base Year 2013*. LEI Report 2014-041, page 36. Wageningen: LEI Wageningen UR. http://www.wageningenUR.nl/en/lei.

van Horne, P. L. M. van, and N. Bondt. 2014. *Competitiveness of the EU Poultry Meat Sector; International Comparison Base Year 2013*. LEI Report 68 (65). Wageningen: LEI Wageningen UR. http:// www.wageningenUR.nl/en/lei.

WABS Consulting Ltd. 2008. *Maize Value Chain Study in Ghana: Enhancing Efficiency and Competitiveness.*Accra, Ghana. http://www.valuechains4poor.org/file/Maize_Value Chain_WAB_Dec_08.pdf.

Wikimedia Commons. 2012. "Regions of Ghana" map. Accessed August 18, 2016. https://commons.wikimedia.org.

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