# Eggs before chickens:

# Poultry, poverty and nutrition in sub-Saharan Africa

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**Abstract**

In the late 1990s a 'livestock revolution' literature documented rapid increases in the consumption and production of animal-sourced foods (ASFs) in transition economies, particularly poultry meat. In Africa, however, ASF consumption growth has been heavily driven by imports, suggesting a missed opportunity to promote domestic agricultural growth and rural poverty reduction. Moreover, a recent focus on nutrition-sensitive agriculture' has catalyzed a growing interest in eggs, which are exceptionally rich in multiple nutrients and highly efficacious in reducing stunting. Yet being largely non-tradable, eggs are typically very expensive in Africa due to low productivity in the layer sector and high feed costs. These issues raise important but thus far unanswered questions surrounding agricultural development strategies in Africa. Should African countries pursue infant-industry policies to reduce their dependence on poultry meat imports, or should they instead focus on improving productivity in the domestic layer sector by addressing high feed costs? And would efforts to improve productivity in the layer sector yield any economic or nutritional benefit for the rural poor, or is agricultural commercialization inevitably urban biased? In this paper we assess these complex issues, first by documenting the more trade-dependent nature of Africa's livestock revolution and its root causes, before turning to an economywide simulation analysis of Ghana. We show that protecting the poultry sector does more harm than good, whereas an ambitious focus on maize productivity renders the layer sector more competitive and improves the affordability of eggs and other ASFs, though more so for urban than rural populations.

**Key words:** Poultry; Eggs; Poverty; Nutrition; sub-Saharan Africa.

***JEL Codes:*** C68, O13, 024, Q17, Q18

## Introduction

In many developing countries the diversification of production and diets into livestock-based products has been occurring for some decades. This so-called "livestock revolution" has been driven by economic growth, urbanization and the transferability of relatively simple livestock production technologies (Delgado, 2003; Delgado *et al.*,1999; 2000; Delgado *et al.*, 2001; Narrod et al., 2008). Poultry has been the leading component of this revolution, largely on the back of easily adoptable production methods and significant economies of scale, allowing many transition economies such as Brazil, China and India to rapidly expand production, domestic consumption and exports of poultry meat. Diversification into high value livestock products – as well as fish (Béné et al., 2015) – has also been an important driver of rural poverty reduction in these countries. Moreover, animal-sourced food (ASF) consumption among infants and young children is strongly linked to lower risks of being stunted (Headey et al., 2018).

In sub-Saharan Africa (SSA) the livestock revolution is also under way on the consumption side, with demand for livestock products being substantially higher than the demand for staples, fruits or vegetables (Colen et al., 2018). Yet on the production side Africa is still lagging, and highly dependent on ASF imports, including imports from Brazil, China, India and other transition economies (Ncube, Roberts, and Zengeni, 2016). The lack of a homegrown livestock revolution in SSA raises two important welfare concerns.

First, Africa's dependence on a wide range of imported high-value agricultural products poses a conundrum for its economic transformation. Countries like Ghana and Nigeria have experienced moderate economic growth and relatively rapid urbanization, but prospects for rapid and sustained growth in household incomes are more contentious (Arbache and Page, 2010; Rodrik, 2016). Africa lacks a strong industrial base, and productivity growth in the large but

unskilled services sector is limited. Given its extensive land base and intensive use of labor, the agricultural sector must play an important role in economic growth and job creation (Diao et al., 2010). Yet an inability to compete with imported agricultural products could clearly retard domestic agricultural growth and rural poverty reduction.

Second, while poultry meat imports can substitute for low productivity in Africa's meat production, eggs are highly perishable and not amenable to long distance imports. As a result, domestic prices of eggs will be set by the productivity of layer production in the domestic economy or neighbouring African economies, which – like productivity in the broiler sector – remains low. As a result, eggs are extremely expensive source of calories in sub-Saharan Africa (Headey et al., 2017). This is nutritionally problematic because eggs are an exceptionally palatable and nutrient-rich food for infants, being rich in high quality protein, as well as a range of micronutrients such as vitamin A and choline that are linked to both immune system functioning and reduced risk of stunting (Iannotti et al., 2014; Lutter et al., 2018). One recent yet very influential trial in Ecuador gave infants in a treatment group free eggs for 12 months and found an exceptionally large reduction in the risk of child stunting of 47 percent (Iannotti et al., 2017). As a result, both nutritional scientists and international development agencies have invested significant resources in evaluations of nutrition-oriented poultry interventions in Africa and Asia (Alders et al., 2018; Beesabathuni et al., 2018; Nordhagen and Klemm, 2018; Dumas et al., 2018; Gelli et al., 2017; Marquis et al., 2018; Olney et al., 2015).

The importance of poultry products for reducing both poverty and undernutrition raises important policy questions that African governments are still grappling with. This paper addresses this question in the context of sub-Saharan Africa in general, before turning to Ghana as a specific case study. Sub-Saharan Africa is a region with marked variation in economic

performance, urbanization and integration with world markets, but with high and quite persistent rates of poverty and undernutrition. Poultry meat is a particularly important traditional food in the region, characterized by high levels of demand increasingly met by imports since the late 1990s. In response, some countries, notably Nigeria, imposed severe restrictions on poultry imports, whilst others, like Ghana, have imposed moderately high tariffs that have failed to seriously curb imports. Eggs are also a highly income-elastic good, but consumption is low because of high prices and low productivity in the layer sector. While there is some variation in import dependence and agricultural productivity in Africa, we argue that our results are highly relevant to Ghana and other coastal African countries that have become increasingly characterized by an import-dependent livestock (and fish) revolution.

This paper's novel contribution is in linking and extending three very different literatures. First, while the original livestock revolution literature was influential in pushing agricultural economics of developing countries to look beyond its traditional focus on staple crops (Delgado, 2003; Delgado *et al.*,1999; 2000; Delgado *et al.*, 2001), this literature focused relatively little attention on Africa and its import dependence, nor on the poverty and nutrition impacts of ASF production and consumption issues.[1]

Second, our study is relevant to literatures on structural transformation and job creation, wherein high value agriculture has an important role to play in African economies that have not managed to create significant numbers of jobs from industry or mining (McMillan, Rodrik and Sepulveda 2017; Diao et al. 2010; Diao et al. 2017).

Third, our analysis constitutes an important contribution to the literature on nutrition-sensitive agriculture, much of it focus on low input-low output traditional poultry production

[1] Trade in livestock products in Africa is a remarkably neglected topic: only one recent study examines competitiveness and trade policy issues in southern Africa (Ncube et al. 2016).

systems (Alders et al., 2018; Beesabathuni et al., 2018; Nordhagen and Klemm, 2018). This literature includes several recent and ongoing randomized control trials that combine poultry interventions with nutritional knowledge interventions (Dumas et al., 2018; Gelli et al., 2017; Marquis et al., 2018; Olney et al., 2015). While relevant to remote communities with very poor access to markets, this literature's focus on small-scale production ignores several important economic and programmatic realities, including the linkages between market access and technology adoption (Morris et al., 2018), very steep economies of scale in the transition from traditional to commercial poultry production (Narrod et al., 2008), the need to improve the economywide affordability of poultry products for both rural and urban consumers, and justified concerns around the sustainability, scalability and cost-effectiveness of projects heavily reliant on intensive behavioural change interventions.[2] In contrast, our study explores the nutritional benefits of larger scale commercialization and international trade on the affordability and consumption of poultry products.

Specifically, this paper addresses two critically important questions. First, how has Africa's livestock-fish revolution played out in terms of consumption, imports and affordability? In Section 2 we address this question by focusing on understanding ASF consumption, trade and pricing patterns in different parts of sub-Saharan Africa, before focusing in on how these patterns playout within Ghana's diverse socioeconomic groups. Ghana is a particularly apt case study, not only because of its dependence on imports, but also because its relatively high level of urbanization suggests an important role for commercial poultry production, even as traditional systems persist for serving rural markets.

[2] Indeed, one of the few NGOs to have implemented smallholder poultry interventions at scale in multiple countries found very limited productivity benefits from their programs, despite some benefits to the nutritional knowledge aspects of the programs (Nordhagen and Klemm, 2018).

Second, what are the impacts of alternative policies on household consumption/poverty and diets in Ghana, and how do these impacts vary by income and urbanization? in Section 3 we use a computable general equilibrium (CGE) model that allows us to examine the welfare impacts of two very distinct scenarios: the adoption of a poultry meat import ban (the Nigerian approach), versus an ambitious achievement of rapid growth in yields of maize, which accounts for 60% of poultry production costs.[3] The rich structure of this model and its underlying data allows us to test the impacts of these two very different policy approaches on total household consumption (an income proxy) and ASF consumption (a diet proxy) for farm, rural non-farm and urban households, and different income groups within each strata.

Our concluding remarks in Section 4 reflect on the implications of our findings for poverty- and nutrition-focused agricultural development strategies, but also for agricultural and nutrition research. On the former, our results suggest that African countries should consider focusing more attention on improving productivity in sectors characterized by natural protection against imports (eggs, and in some cases, fresh dairy and fish), since these sectors contribute to poverty reduction as well as nutritional objectives. Research-wise, we believe that CGE models provide a highly effective tool for improving our understanding of the livestock revolution, including a more systematic exploration of the nutritional implications of alternative policy actions.

**Revolution redux: Consumption and trade of animal-sourced foods in sub-Saharan Africa**

In this section we first review some basic features of the livestock revolution in Asia and Latin America documented by Delgado and colleagues, among others. We then turn to a more detailed

[3] For Ghana, the flagship agricultural development intervention, Planting for Food and Jobs, anticipates more than a two-fold increase in maize productivity in the medium term (three years).

description of how the livestock revolution is unfolding in sub-Saharan Africa, particularly its greater dependence on imports and its influence on prices, before conducting a more granular analysis of how ASF consumption patterns vary by region, urbanization and wealth in Ghana.

***The original livestock revolution in China, Brazil, India and other transition economies***

The livestock revolution documented by Delgado et al. largely focused on livestock consumption and production trends (not fish) in East Asia (mainly China) and, to a lesser extent, Latin America (mainly Brazil) and South Asia (mainly India). Although these countries have become successful producers of a wide range of ASFs, poultry meat production has taken off rapidly. Relative to other meats, poultry is remarkably efficient in terms of the amount of feed required to produce one kilogram of animal weight, known as the feed conversion ratio. For efficient operations, this feed conversion ratio is about 1.7 for broilers compared with about 3.0 for pork and more than 10.0 for beef (Tolkamp *et al.*, 2010). Poultry's efficient feed conversion has made it the fastest-growing ASF and this has encouraged intensive production. The move toward intensive production has been accompanied by clustering of farms around processing centres, and vertical coordination of broiler production with meat processing (Martinez, 2002; Steinfeld *et al.*, 2006).

International trade in chicken meat has also expanded rapidly. Data from the United Nations food and agriculture database (FAO, 2017) and the United States Department of Agriculture (USDA, 2003; 2009; 2010; 2017) confirm that chicken meat has led growth in meat exports over the past three decades. In 1990, the quantity of beef exported (4,323,000 metric tons) was nearly double the quantity of chicken meat exported (2,201,000 metric tons). By 2010, the situation had reversed with the quantity of chicken meat exports (11,654,000 metric tons) close to double the quantity of beef exports (6,913,000 metric tons). This remarkable growth in

chicken meat trade has taken place despite tariff and nontariff trade barriers in many importing countries (Josling *et al.*, 2001).

***The Livestock-Fish Revolution in Sub-Saharan Africa***

While demand for ASFs seem universally strong in Africa (Colen et al. 2018), the supply side may well be a different story Rich (2009). In Asia and Latin America, rapid growth in local production met growing local demand, but African markets – particularly coastal areas - are already being supplied with meat by highly productive exporters operating very efficient cold distribution network. African producers therefore face a level of international competition that was not present two to three decades ago. Unsurprisingly, many African governments have been tempted into protectionism. On the back of rapidly growing imports since the late 1990s, Nigeria banned imports of chicken meat in 2002. Ghana applied and quickly revoked a 40 percent tariff in 2003, and since then has allowed imports, maintaining a 20 percent tariff until the adoption of the ECOWAS Common External Tariff of 35 percent in 2016.

Table 1 demonstrates the importance of imports to per capita consumption growth in ASF calories in Ghana, Nigeria and other regions of SSA over 1993-2013. In this 20-year period, poultry consumption in Ghana rose from just 2 calories per day to 19 calories in 2013, whereas official FAO consumption statistics show no change in poultry consumption in Nigeria. In practice, available evidence suggests that consumption of poultry products in Nigeria is growing due to smuggling via Benin and other countries.[4] Also notable in Table 1 is that, although

[4] Reasonably strong evidence of smuggling of imported frozen chicken meat into Nigeria via Benin provides a partial explanation. United Nations Comtrade data indicate a surge in frozen chicken meat imports into Benin just as official Nigerian imports declined to effectively zero (UN, 2017). Based on these data, and by making the reasonable assumption that chicken meat consumption in Benin has been similar to consumption in other West African countries, we estimate that around 112,000 metric tons of chicken meat imported into Benin were smuggled into Nigeria annually from 2010 to 2015. Liverpool-Tasie et al. (2016) have used a variety of data sources to estimate that illegal imports accounted for 50 million birds consumed in Nigeria in 2010, which would add up to 100,000 metric tons of imports, assuming a weight of 2 kilograms per bird. If one assumes that these smuggled quantities were excluded from official consumption statistics, then Nigeria's chicken meat consumption rose slightly

chicken meat is the fastest growing source of ASF calories in Ghana and other coastal African countries, fish remains the dominant source despite its stagnation over time.

In other coastal West African countries chicken meat consumption almost tripled over this period, although other coastal African economies also experienced rapid consumption growth. In contrast, landlocked countries saw virtually no change in consumption of poultry meat. Access to low cost imports explains much of this disparity between coastal and landlocked countries. In Ghana, imports accounted for 83% of consumption growth over this period. By 2013 imports provided the majority of calories for dairy (83%) and fish (77%) as well, and almost half of the calories for poultry, dairy and fish in other coastal West African countries. Appendix Table A1 shows a dramatic contrast between coastal Africa and non-African developing regions, with significantly less dependence on ASF imports in all regions, despite the growing importance of trade in ASFs.

**[insert table 1 about here]**

Another striking but unsurprising conclusion from Table 1 is that unprocessed eggs are clearly not commonly traded over long distances. Eggs do not appear to be imported at all in Ghana and Nigeria, although cross-border trade has seemingly played some role in small increases in egg consumption in other West African countries. In other African regions, however, egg trade is low relative to total consumption and consumption growth. Moreover, scarcely any

to 1.50 kilograms per capita by 2011-2015, rather than declined. Indeed, based on data from Nigeria's Living Standards Measurement Survey (LSMS), Liverpool-Tasie et al. (2016) estimate per capita meat consumption in Nigeria to be about 2 kilograms per capita in 2010. Local production of chicken meat rose slightly by 1.45 percent on average per year (2000-2016), along with increasing demand, as smuggled chicken meat did not offset the decline in official imports to effectively zero.

of this trade involves long distance trade from high productivity transition or developed economies,

Limited access to eggs from high productivity countries would imply that eggs prices in Africa are heavily determined by the productivity of domestic egg value chains. Where domestic poultry is dominated by traditional scavenging systems, production is largely geared towards sales of live animals because high rates of mortality preclude eggs being profitable (in contrast, live birds can be sold for meat whilst still young). With limited production of eggs, one would expect prices to be extremely high.

A recent study on the affordability of ASFs constructs ratios of the price of an ASF calorie relative to the price of the cheapest staple cereal in a country, thereby circumventing currency conversion issues (Headey et al. 2018). Comparisons of these relative calorie prices for different ASFs are presented in Table 2 (see also Appendix Table A2 for some specific product prices). Table 2 shows that egg calories are 9.2 times as expensive as maize calories in Ghana, compared to ratios of 6.3 for red meat, 5.5 for chicken meat, 5.0 for fish and just 3.4 for milk powder. Similar patterns hold for Nigeria, where eggs are somewhat more affordable relative to chicken meat,[5] and for other coastal West African countries. In landlocked West Africa and other sub-Saharan African countries, we observe equally high relative prices of eggs, but much higher prices of chicken meat, consistent with their lower access to imported poultry meat.

Also of note is that the extremely high price of eggs in Africa is a marked contrast to other developing regions, where the livestock (poultry) revolution has long since taken off. Egg calories are just 5-7 times as expensive as staple cereal calories in most other developing regions, and just 3.6 times as expensive in Europe and Central Asia.

[5] The relatively low price of chicken meat if further evidence that smuggling from Benin and other countries is an important part of poultry supply in Nigeria.

**Insert Table 2 about here]**

### *ASF consumption patterns and prices in Ghana*

A serious limitation of the statistics provided above is their lack of subnational disaggregation, particularly given concerns and expectations that commercial food systems largely cater to urban or coastal populations (von Braun 1994). However, official retail market price data for poultry products are not sufficiently standardized to draw clear comparisons over regions or rural/urban locations. That data do suggest that frozen chicken prices may be much lower in Accra, the capital and largest city, than in other regional capitals, but prices for live animals and eggs show few clear patterns except being cheaper near the Benin border. Egg price data from the Ghana Living Standards Survey (GLSS) of 2018 surprisingly show that egg prices in rural and urban areas are similar, although these prices are not necessarily adjusted for size or weight.

GLSS data also show strikingly different ASF expenditure patterns (Appendix Table A3) for poor and non-poor households. Non-poor households spend around 4 percent of their ASF budgets on eggs compared to just 1 percent for poor households. GLSS data also report egg consumption over a 30-day recall period. Average egg consumption in Ghana is 2.86 eggs per person as recalled over a 30-day period, or roughly 35 eggs per capita per annum, with much lower egg consumption among poor households (Appendix Figure A1). The national average of 35 eggs falls far below the global estimated average of 200 eggs per capita per annum and is around half of the per capita egg consumption in countries such as India (International Egg Commission, 2013). GLSS data reveal that frozen chicken meat is much more affordable for the poor, with differences in ASF expenditure shares across poor and non-poor households much lower (4 percent and 6 percent). This finding suggests that frozen chicken imports may have

penetrated rural markets as well as urban and are sold at affordable prices, although this is less true of northern Ghana where frozen chicken accounts for just 1 percent of ASF expenditure.

Although eggs are very expensive, infants and young children only require small quantities, perhaps making them affordable as a complementary food for even relatively poor households. We therefore use DHS data to examine ASF consumption patterns for both children 12-23 months of age (24-hr recall) as well as patterns in child stunting. Table 3 shows very stark regional, rural-urban and wealth differences for both stunting and ASF consumption. Stunting is lowest in Accra (<10%) and highest in the north (>40%), but highly concentrated among the poor: almost one third of children 24-59 months are stunted in the two poorest quintiles, whereas less than 12% of children in the richest two quintiles are stunted.

ASF consumption patterns prior to 2 years of age could well explain much of this wealth gradient in stunting. Amongst all ASFs, fish is by far the most commonly consumed ASF among children (52.7%), but even poor children consume fish frequently. In contrast, egg consumption is low on average (22.4%) (although higher in Ghana than in many African countries – see Headey et al. 2018), and similar to dairy and fish. However, the wealth disparity in egg consumption is large indeed: while just 6.4% of the poorest children consume eggs, 46% of the richest children do so. This disparity also exists for dairy and meat, but not for fish. Overall, then, fish appears highly affordable for the poor and possibly an inferior good, while eggs, red/white meat and dairy are evidently out of reach for the poor but characterized by high income-elastic demand.

**[Insert Table 3 about here]**

**Can Africa improve the poverty and nutritional impacts of its livestock revolution?**

The previous section illustrated how extraordinarily import-dependent livestock consumption in African countries has become, with important implications for rural poverty reduction and nutrition. As African countries urbanize and grow economically, it is vital that growing demand for high value foods in urban areas catalyse the transformation of agriculture into producing those higher value foods if they have the basic economic and agronomic potential to do so (Reardon et al. 2012; Tschirley et al. 2015). Modern poultry production technologies are strikingly homogenous and adaptable to a range of agroclimatic conditions, but African broiler firms face particularly high feed costs that render them uncompetitive relative to exports (Andam et al. 2017). African governments therefore face pressure to invoke protection based on infant industry argument, but the egg/layer sector is naturally protected and could be assisted through domestic investments to reduce the price of feed, with potential benefits for improving egg consumption through significant reductions in the prices of eggs. Whether efforts to assist heavily commercialized agricultural sectors would yield significant benefits for the rural poor, however, is much more uncertain (von Braun 1994). To address these questions, we employ a detailed economywide model of Ghana to examine the expected impacts on household consumption in 2025 from two alternative policy options for the poultry sector (meat and eggs): a protectionist policy for the broiler sector, and a feed-investment policy for the naturally protected layer sector.

***Modelling alternative policy scenarios in Ghana***

We develop a dynamic recursive computable general equilibrium (CGE) model called the Rural Investment and Policy Analysis (RIAPA) model.[6] RIAPA is a variant of the International Food

[6] A dynamic model accounts for the fact that the poultry sector is currently a relatively small part of Ghana's economy (Diao, 2009).

Policy Research Institute (IFPRI) model described in Lofgren et al. (2002) and Thurlow *et al.* (2012). It is a descendant of the class of CGE models introduced by Dervis, de Melo, and Robinson (1982). CGE models, such as RIAPA, are useful for counterfactual analysis as they provide a simulation laboratory of the economy. Further details of the model are given in Appendix B; here we given only a basic overview of the model's central features, particularly as they pertain to the poultry meat and egg sectors.

The dynamic recursive CGE model used here is based on a 2015 national social accounting matrix (SAM) for Ghana, consisting of 56 activities and 58 commodities. Households are divided into 15 household groups representing the quintile income distribution in rural farm, rural nonfarm, and urban households. Other institutions, (i.e., government, enterprises, and the rest of the world) are also represented, and key taxes present in the SAM include direct taxes on incomes, sales taxes, export tariffs, and import duties.

Though otherwise similar to earlier CGE models for Ghana, this SAM is modified to include a more detailed poultry sector. Like a previous application of an economywide model to the poultry sector (Diao, 2009), poultry production is divided between layers, which face essentially no import competition, and broilers, which compete directly with imports of frozen meats. Poultry producers are also split into commercial broilers, commercial layers, and a traditional layer and broiler sector, and poultry outputs are also disaggregated into commercial and traditional chicken meat and eggs. Data from value chain studies that have documented production costs, the state of the feed sector, and current prices (Andam *et al.*, 2017; Amanor-Boadu *et al.*, 2016) were used to inform the construction of the baseline scenario and the two policy scenarios. Of importance to the results are assumptions about the flow of products from these different types of producers. The commercial layer and broiler sectors are assumed to cater

chiefly to urban populations. However, imported poultry meat is also consumed by rural households, while the traditional egg sector sells its products in both rural and urban sectors, resulting in a high degree of integration between rural and urban egg markets. These structures are consistent with stylized findings from the previous section, in which it was shown that frozen poultry meat (mostly imported) is widely consumed in rural areas, while egg prices exhibit relatively little variation across different cities and rural and urban areas.

***Model Scenarios***

The baseline and two alternative policy scenarios are run for 10 years to assess divergence in household welfare outcomes in 2025. The dynamic recursive CGE model is first run over 2015-2025 to develop a baseline growth path in which the Ghanaian economy is assumed to grow at an average annualized rate of 5.8% between 2015 and 2025, in line with projections by the International Monetary Fund (IMF, 2017), and with the structure of the economy relatively unchanged (see Appendix Table A2).

The baseline model is then shocked with two alternative policy scenarios.

(1) Stricter chicken meat tariffs. The high tariff scenario is modelled to assess the Nigerian strategy of an effective export ban on poultry meat imports. Specifically, we increase the effective tariff on imported chicken meat gradually over the 10-year period to reach 350% by 2025 (UNCTAD, 2015).

(2) Rapid productivity growth in maize yields. An alternative to protectionism is to invest in the domestic poultry value chains. Previous analyses of constraints in these value chains in Ghana suggest that high feed costs are a binding constraint (Sumberg *et al.*, 2017; Andam et al. 2017). Maize accounts for 60% of feedstock costs, and Table 4 suggests that yellow maize costs for feed mills are 68.1% higher than the international FOB price. High costs are primarily related

to low maize yields in Ghana. White and yellow maize productivity is therefore increased by 10% per annum over the model period (an increase of 2% is assumed in the baseline). This is an ambitious scenario, but actually well below the government's stated targets whilst still within the realms of technically achievable growth given that maize yields in Ghana are well below their agronomic potential.

**[insert Table 4 about here]**

***Model Results***

Figure 1 depicts the main price outcomes under the two scenarios. Relative to the baseline scenario, the economy-wide price of chicken meat increases by 124% under the protectionist trade policy scenario, from GHS 8 per kg in 2015 to GHS 17.91 per kg in 2025. This price increase is primarily driven by higher-priced commercially produced chicken meat, which provides the bulk of total domestic chicken supply in Ghana. In contrast, lowering feedstock costs through increasing white and yellow maize productivity results in an increase in local poultry production with an associated decline in prices. Economy-wide chicken meat and egg prices are lower by 1% and 8% respectively in this scenario in 2025 compared with 2015, with the larger reduction in egg prices reflecting the lack of any effective competition from imports (Figure 1).

**[insert Figure 1 about here]**

Figure 1 also shows the mechanism for the declining poultry product prices in the second scenario. As maize accounts for about 60% of feedstock costs, increasing maize productivity results in a decline in feedstock prices. Output of white and yellow maize increases by 19% and 36% resulting in the price of white and yellow maize declining by 45% and 39% respectively by 2025 (Figure 1). Cheaper feedstock costs also have a large positive impact on commercial

chicken meat production which increases by 84% by 2025 (albeit from a small base), while commercial and traditional egg production (a much larger sector in 2015) increase by 7% and 10%.

Table 5 provides estimates of the poultry consumption effects in the two alternative scenarios by household income quintiles in rural farm, rural non-farm and urban households. The rise in chicken meat prices under the import ban scenario results in a disastrous decline in household chicken meat consumption, on the order of 67-84% on across all economic groups relative to baseline, and 78% for the average consumer. The fact that chicken meat declines by 71% for the average rural consumer shows that protection of poultry meat imports yields no benefit for the typical smallholder farmer. The import ban on meat actually results in a slightly lower price of eggs (which decrease by 0.6%) due to cheaper capital, however, and therefore a small increase in the consumption for eggs of 0.6% across all households.[7]

Again, the outcomes are very different when feedstock costs are reduced. Lower chicken meat and egg prices result in an increase in household consumption of both commodities. Egg consumption increases in the range of 13-16% among urban quintiles, 15-17% among rural non-farm quintiles and 19-20% among rural farm households. The increases in meat consumption are much more modest because of the smaller decline in poultry meat prices (Figure 1), and are relatively modest in rural farm households (1.5 to 4%) and rural non-farm households (4-6%) compared to urban households (5-7%). It is worth noting that in absolute (per capita kg) terms,

[7] The mechanism for the outcomes under the import ban scenario merit further explanation. The simulated increase in the import tariff raises the price of imported chicken meat by 340%, discouraging demand for chicken meat imports. The quantity of chicken meat imported decreases to effectively zero by 2025 relative to the baseline scenario. This decrease in supply, along with continued demand for chicken meat, provides a more encouraging environment for domestic producers. Domestic poultry value added increases by 120% relative to the baseline of no tariff change. This increase is concentrated in the broiler industry where value added increases more than fivefold. Layer farms also produce chicken meat as a by-product of egg production. This sub-sector also experiences an increase in value added although this is largely driven by the availability of cheaper livestock capital. Value added by commercial and traditional layers increases by 0.45% relative to the baseline.

however, the consumption of eggs remains relatively low in 2025 by international standards, although the increases in egg consumption are substantially higher in rural areas and in lower consumption quintiles. In large part this reflects the higher income elasticities for egg products among these populations, even though income elasticities for eggs are lower than they are for poultry meat. This perhaps suggests that meaningful increases in egg consumption among young children may require promotional campaigns through mass media or public health interventions.

**[insert Table 5 about here]**

Figure 2 shows that overall food consumption is also higher when maize productivity increases, consistent with previous research showing the important income and poverty reduction effects of improving productivity in key staples in African economies in which poverty remains highly rural, farm and rural non-farm sectors are highly integrated, and staples still form a large component of the diet (Diao et al. 2010). Total household food consumption increases by 3.8%. Within rural areas, total food consumption is 4.0% higher; while in urban areas food consumption increases by 3.5%. Consumption of own production increases by more than the consumption of marketed commodities for both rural and urban households. For rural farm households, non-food consumption decreases as returns from land and capital are lower than in the baseline scenario because of increased maize productivity (less land is needed to produce the same amount of crop).

**[insert Figure 2 about here]**

The total household consumption outcomes under the import ban are generally unfavourable, albeit modestly so (Appendix Figure A2). The knock-on impacts of more expensive chicken meat result in a decline in overall food consumption in both rural (-0.4%) and urban households (-1.3%) by 2025. For lower income rural farm households, consumption is

modestly higher as the change in returns from livestock capital and land is higher in the import ban scenario.

In summary, a ban on poultry imports – the Nigerian approach - yields very minor benefits for poorer rural households, but results in welfare losses for other socioeconomic groups. The ambitious gains in maize productivity in the improved feed scenario result in a substantial decline in egg prices, and raise egg consumption considerably, especially for poor populations that stand to benefit from improved access to a highly nutritious food. Moreover, increased maize productivity has substantial real income effects for all swathes of the population. Whether these increases in egg consumption at the household level suffice to significantly improve egg consumption among infants and young children – nutritionally the most vulnerable age group (Victora et al. 2009) – remains to be seen; but the reduced prices of eggs and income gains form maize productivity growth would certainly improve the affordability of eggs as a regular complementary food for this age group.

**Conclusions**

This article began by noting that the livestock consumption trends identified in the livestock revolution (Delgado *et al.*, 1999) are now playing out in Africa (Zhou and Staatz 2016; Tschirley *et al.* 2015; OECD/FAO 2016). However, we show that ASF consumption growth in coastal Africa – particularly West Africa – is heavily driven by growth in imports, often from highly efficient producers operating at scale and distributing via an efficient global cold chain to Africa's urban centres. Africa therefore faces a very different playing field from those original livestock revolution countries, and stands at a crossroads in terms of electing protectionist

approaches that hurt consumers, or more strategic approaches focused on improving domestic productivity.

As this paper shows for Ghana in the period 2015–2025, protectionism leads to a local supply response – yet not one that will be based on improved competitiveness (Easterly, 2001; Newman *et al.*, 2016; Rodrik, 2016)[8] - and an adverse net result for consumers resulting from much higher poultry meat prices, much lower meat consumption and even small aggregate consumption losses. In practice, a large tariff wedge between domestic and world prices of chicken meat will encourage smuggling, with attendant risks and administrative burdens. All of these impacts—a local supply response, attenuated demand growth for chicken meat, and smuggling of frozen chicken meat—occurred in Nigeria (Liverpool-Tasie et al. 2017).

For Ghana, and probably for many other countries in SSA, the results in this paper point to a middle path. Egg production is currently large relative to chicken meat production and naturally protected from deep-sea imports due to the difficulties of transporting eggs across oceans in Ghana and almost all African countries. This situation offers a low-cost and low-risk opportunity to develop capabilities for an internationally competitive poultry sector by focusing on eggs in the near term. International competitiveness in chicken meat production hinges crucially on inexpensive sources of balanced poultry feed rations. Improving productivity in maize is a particularly attractive option because of its huge real income effects across broad segments of society (Diao et al. 2010), by substantially reducing the prices of eggs, and by reducing feed costs in other livestock sectors, such as aquaculture. Indeed, while Ghana does not manifestly possess endowments that would confer a substantial global advantage in poultry

[8] Unless some key social objectives are attained via the trade protection policy and other, more efficient, instruments for achieving these objectives are impractical to deploy.

production, the presence of the world's largest man-made lake may confer real advantages in aquaculture production (Ragasa *et al.*, 2018).

Our analysis also sheds important light on the role for large-scale commercial agriculture to improve nutrition outcomes. The vast majority of the burgeoning literature on nutrition-sensitive agriculture is heavily focused on smallholder farmers operating in semi-subsistence economies, engaged in very localized marketing channels. Smallholders are undoubtedly a major component of agricultural production as a whole, and potentially be very efficient in a range of labor-intensive crops and livestock sectors, including dairy. Poultry production (broilers and layers) is an important exception, however, characterized by tremendously steep economies of scale. Our results suggest that in a middle income and relatively urbanized economy such as Ghana, production by commercial layers will be the main driver of economywide egg prices. Moreover, since income elasticities for eggs are higher for poorer populations, the poor – including the rural poor – see the largest increases in egg consumption on the back of lower egg prices and larger income gains from maize productivity growth.

This result is highly relevant to the expanding literature on agriculture and nutrition insofar as it contradicts two widely held tenets in the literature. The first is that dietary diversification requires commensurate diversification of agricultural investment portfolios. Public investment in non-staple food sectors is not obviously the surest means to increase ASF consumption because high feed costs are a constraint for multiple livestock sectors (eggs, dairy and aquaculture, for example).[9] This is not to say that livestock sectors do not face other constraints, but it may often

[9] As this analysis has focused on changes in the poultry sector from the feedstock improvement scenario, we have not computed the improved production in other sectors that would result from improving maize productivity, and therefore the benefits from pursuing feedstock cost reduction are likely understated in this paper (Table A5). Note

be the case that high feed costs are a binding constraint. To be trite, neither the egg nor the chicken comes first; the feed comes first.

Second, an older literature on agricultural commercialization and nutrition – admittedly often focused on cash crops – has cast widespread scepticism that commercial production systems any nutritional benefits for the rural poor. In the case of poultry, Ghana – like most African countries – has a highly dualistic structure characterized by large commercial poultry farms (mostly layers) and smallholder poultry production best characterized as part-time, low input and low output, and mostly geared towards live animal sales (depending on bird mortality rates and access to markets). It is conceptually possible that growth in the commercial layer sector induces some welfare losses to some segments of the rural population, but unlikely because most households engage in maize production (benefiting substantially from any yield improvements) and very few would be large net sellers of eggs who would incur serious welfare losses from lower egg prices. Our results also suggest that poor's higher income elasticities for eggs lead to greater consumption gains.

Finally, we offer a quick reflection on areas for further research. Our study is obviously specific to poultry in Ghana, but Africa is diverse, and livestock sectors are structurally different. These two dimensions of diversity make understanding and analysing Africa's unique livestock revolution a challenging task. Landlocked countries may be less exposed to poultry imports, for example, but not to fish (Table 1), warranting case study analyses for different types of ASFs in different types of countries. This paper also focuses substantial attention on feed constraints, but

that in Table A5 the cost of grain milling goes down by 10% when maize prices are reduced through the maize productivity scenario.

there is surprisingly little analysis of feed costs in different sectors in different African economies, despite feed costs comprising such a high share of total production costs. This study also focuses solely on maize feed, but soybeans are an important component of livestock feed. As a tropical crop, soybeans have considerable potential in sub-Saharan Africa, and their production has expanded rapidly in many countries. Yet again, scarcely any research has touched on the implications of this expansion for Africa's livestock revolution, or the important objectives of reducing rural poverty and childhood undernutrition.

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## Tables and figures

**Table 1. Trends in per capita calorie consumption from different animal-sourced foods in Ghana, Nigeria and other sub-Saharan African regions**

| | Eggs | Poultry | Milk | Fish | Other meat |
|---|---|---|---|---|---|
| **Ghana** | | | | | |
| 1993 | 2 | 2 | 5 | 54 | 43 |
| 2013 | 4 | 19 | 13 | 58 | 36 |
| Change | 2 | 17 | 8 | 4 | -7 |
| Import share of change | 0% | 83% | 103% | 765% | NA |
| **Nigeria** | | | | | |
| 1993 | 12 | 4 | 11 | 12 | 31 |
| 2013 | 12 | 4 | 12 | 26 | 37 |
| Change | 0 | 0 | 1 | 14 | 6 |
| Import share of change | 0% | 0% | 125% | 126% | 1% |
| **Other coastal West Africa** | | | | | |
| 1993 | 3 | 6 | 37 | 30 | 45 |
| 2013 | 6 | 17 | 34 | 29 | 45 |
| Change | 2 | 11 | -3 | -1 | 1 |
| Import share of change | 21% | 47% | 322% | NA | NA |
| **Other coastal sub-Saharan Africa (Eastern, Central, Southern)** | | | | | |
| 1993 | 7 | 20 | 65 | 17 | 90 |
| 2013 | 9 | 45 | 69 | 16 | 91 |
| Change | 2 | 25 | 5 | -2 | 2 |
| Import share of change | 47% | 27% | 45% | NA | 94% |
| **Landlocked West Africa** | | | | | |
| 1993 | 4 | 7 | 79 | 6 | 66 |
| 2013 | 4 | 7 | 117 | 10 | 74 |
| Change | 0 | 0 | 39 | 4 | 8 |
| Import share of change | 0% | 0% | 1% | 66% | 2% |
| **Other landlocked sub-Saharan Africa (Eastern, Central, Southern)** | | | | | |
| 1993 | 3 | 4 | 30 | 7 | 47 |
| 2013 | 3 | 5 | 55 | 8 | 53 |
| Change | 0 | 1 | 25 | 1 | 5 |
| Import share of change | NA | 6% | 8% | 70% | 2% |

Source: Authors' calculations from FAO (FAO, 2018) data.

**Table 2. Prices of animal-sourced food calories relative to the cheapest cereal calorie in different countries and regions (population weighted**

| | Eggs | Poultry | Milk powder | Fish | Other meat |
|---|---|---|---|---|---|
| Ghana | 9.2 | 5.5 | 3.4 | 5.0 | 6.3 |
| Nigeria | 8.5 | 5.8 | 3.0 | 4.2 | 6.1 |
| Other Coastal West Africa | 10.9 | 5.9 | 4.6 | 4.9 | 6.8 |
| Other Coastal SSA | 9.2 | 8.2 | 5.6 | 5.1 | 6.2 |
| Other landlocked West Africa | 11.9 | 11.8 | 4.2 | 5.9 | 7.0 |
| Other landlocked SSA | 8.8 | 9.5 | 6.1 | 5.7 | 5.7 |
| South Asia | 4.9 | 6.0 | 2.5 | 3.9 | 4.6 |
| East Asia & Pacific | 8.7 | 6.1 | 7.7 | 5.3 | 8.0 |
| Latin America & Caribbean | 5.0 | 3.1 | 3.7 | 5.0 | 6.8 |
| Middle East & North Africa | 5.0 | 5.4 | 2.4 | 3.9 | 11.6 |
| Europe & Central Asia | 3.6 | 2.5 | 3.6 | 4.0 | 5.4 |

Source: Authors' estimates from the International Comparison Program (ICP) data from the World Bank (World-Bank, 2015), and USDA calorie conversion factors (USDA, 2017).

**Table 3. Child stunting and animal sourced food patterns in Ghana, 2014**

| | Stunting (24-49m) | ASF consumption in past 24 hrs (12-23m) | | | |
|---|---|---|---|---|---|
| | | Eggs | Fish | Meat | Dairy |
| **All Ghana** | 22.5% | 22.4% | 52.7% | 18.7% | 21.2% |
| **Urban** | 15.6% | 33.7% | 55.4% | 24.5% | 35.5% |
| **Rural** | 28.2* | 12.1% | 50.3% | 13.4% | 8.1% |
| **Wealth quintile** | | | | | |
| Poorest | 31.9% | 6.4% | 45.6% | 9.3% | 6.0% |
| Poorer | 31.6% | 20.8% | 53.6% | 17.2% | 8.7% |
| Middle | 21.8% | 19.4% | 59.0% | 18.5% | 9.3% |
| Richer | 12.0% | 29.6% | 55.2% | 20.6% | 35.1% |
| Richest | 10.3% | 46.3% | 57.7% | 25.6% | 56.3% |
| **Coast** | | | | | |
| Greater Accra | 8.7% | 37.9% | 63.2% | 39.6% | 57.3% |
| Volta | 22.9% | 26.4% | 49.4% | 10.8% | 7.3% |
| Central | 26.9% | 19.4% | 81.9% | 15.5% | 28.7% |
| Western | 20.6% | 36.8% | 47.3% | 13.3% | 22.0% |
| **Center** | | | | | |
| Ashanti | 19.9% | 13.7% | 38.2% | 15.6% | 8.7% |
| Brong Ahafo | 17.0% | 20.4% | 71.0% | 19.2% | 11.5% |
| Eastern | 19.9% | 18.8% | 35.9% | 7.7% | 15.9% |
| **North** | | | | | |
| Northern | 46.7 | 9.7% | 43.7% | 16.3% | 8.7% |
| Upper East | 28.4 | 5.5% | 23.6% | 18.0% | 8.9% |
| Upper West | 19.4 | 18.5% | 38.1% | 9.0% | 2.2% |

Source: Authors' estimates form the 2014 DHS

**Table 4. Feed ingredient costs in Ghana compared with international prices, 2016 (US$/ton)**

| | Ghana feed mills prices | International FOB price | Ghana premium (%) |
|---|---|---|---|
| Yellow maize | 268.79 | 159.9 | 68.10% |
| Fishmeal | 1128.79 | 1566 | -27.92% |
| Soybean | 500.00 | 382.04 | 30.88% |
| Wheat bran | 103.41 | NA | NA |
| Total feed cost[a] | 380.16 | 328.948 | 15.57% |

Sources: Ghana prices are derived from IFPRI interviews with commercial feed mills in Kumasi and Accra (2016). International prices are derived from FAO Food Price Monitoring and Analysis data (yellow maize and soybean) and FAO Commodity Statistics Update (fishmeal).

Note: Yellow maize is Argentine, Rosario, wholesale maize (yellow). Fishmeal is 64/65%, any origin, wholesale, CIF Hamburg. Soybean is US No. 1 Yellow (Gulf). a. Total feed costs are based on composition by volume

**Table 5. Poultry meat and egg consumption in 2025 under different model scenarios**

| | | | Eggs kg/capita | Change (%) | Meat kg/capita | Change (%) |
|---|---|---|---|---|---|---|
| Rural farm households | Q1 | Baseline | 1.2 | | 0.6 | |
| | | Import ban | 1.2 | 0.6% | 0.2 | -71.0% |
| | | Feed improvement | 1.4 | 19.1% | 0.6 | 1.5% |
| | Q2 | Baseline | 1.9 | | 0.8 | |
| | | Import ban | 1.9 | 0.5% | 0.3 | -66.3% |
| | | Feed improvement | 2.2 | 19.0% | 0.9 | 2.3% |
| | Q3 | Baseline | 2.3 | | 1.1 | |
| | | Import ban | 2.3 | 0.5% | 0.4 | -65.4% |
| | | Feed improvement | 2.8 | 18.7% | 1.2 | 2.7% |
| | Q4 | Baseline | 2.9 | | 1.8 | |
| | | Import ban | 2.9 | 0.5% | 0.6 | -67.4% |
| | | Feed improvement | 3.5 | 18.9% | 1.8 | 3.3% |
| | Q5 | Baseline | 4.4 | | 3.2 | |
| | | Import ban | 4.4 | 0.4% | 0.9 | -73.4% |
| | | Feed improvement | 5.3 | 20.3% | 3.3 | 3.9% |
| Rural non-farm households | Q1 | Baseline | 0.5 | | 0.7 | |
| | | Import ban | 0.5 | 0.4% | 0.2 | -75.2% |
| | | Feed improvement | 0.6 | 17.1% | 0.7 | 3.7% |
| | Q2 | Baseline | 1.0 | | 1.2 | |
| | | Import ban | 1.0 | 0.4% | 0.3 | -70.1% |
| | | Feed improvement | 1.2 | 16.1% | 1.2 | 4.0% |
| | Q3 | Baseline | 1.1 | | 1.5 | |
| | | Import ban | 1.1 | 0.4% | 0.5 | -69.9% |
| | | Feed improvement | 1.3 | 14.7% | 1.6 | 4.4% |
| | Q4 | Baseline | 1.9 | | 2.9 | |
| | | Import ban | 1.9 | 0.4% | 0.8 | -72.7% |
| | | Feed improvement | 2.2 | 15.1% | 3.1 | 5.1% |
| | Q5 | Baseline | 3.7 | | 5.7 | |
| | | Import ban | 3.7 | 0.4% | 1.1 | -80.0% |
| | | Feed improvement | 4.3 | 16.9% | 6.0 | 5.9% |
| Urban households | Q1 | Baseline | 1.7 | | 2.9 | |
| | | Import ban | 1.7 | 0.9% | 0.5 | -80.8% |
| | | Feed improvement | 2.0 | 15.8% | 3.0 | 5.0% |
| | Q2 | Baseline | 1.0 | | 1.5 | |
| | | Import ban | 1.0 | 0.8% | 0.4 | -72.3% |
| | | Feed improvement | 1.1 | 14.5% | 1.6 | 5.0% |
| | Q3 | Baseline | 1.5 | | 2.5 | |
| | | Import ban | 1.5 | 0.7% | 0.7 | -73.3% |
| | | Feed improvement | 1.7 | 13.9% | 2.6 | 5.4% |
| | Q4 | Baseline | 1.7 | | 3.1 | |
| | | Import ban | 1.7 | 0.7% | 0.7 | -76.1% |
| | | Feed improvement | 1.9 | 13.5% | 3.3 | 6.0% |
| | Q5 | Baseline | 2.5 | | 5.4 | |
| | | Import ban | 2.5 | 0.8% | 0.9 | -84.2% |
| | | Feed improvement | 2.8 | 13.1% | 5.8 | 6.7% |

**Figure 1. Changes in the real prices of poultry meat, eggs and white and yellow maize (2015 cedis/kg) under different model scenarios**

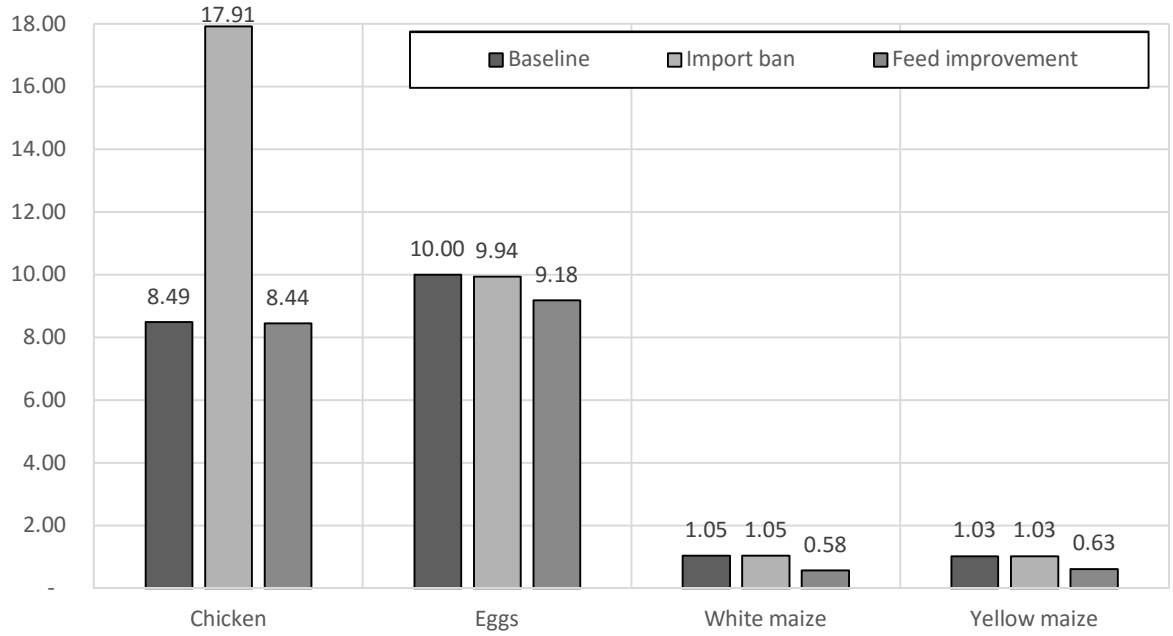
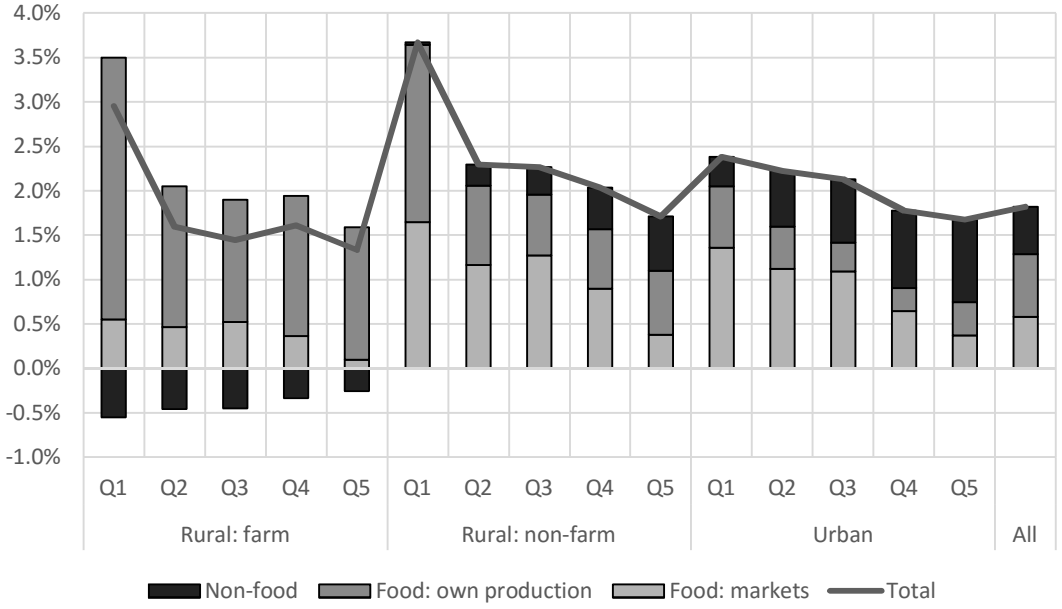


**Figure 2. Change in real household consumption (%) from the baseline to the improved feed scenario, by rural and urban consumption quintiles**



## Appendix

**Table A1. Trends in animal-sourced food calories in developing countries between 1993 and 2013, and the share accounted for by imports (population-weighted means)**

| | | Eggs | Poultry | Fish | Other meat | Milk |
|---|---|---|---|---|---|---|
| East Asia | 1993 | 29.9 | 24.3 | 26.0 | 190.8 | 14.0 |
| & Pacific | 2003 | 59.0 | 58.3 | 53.2 | 330.7 | 49.0 |
| | Change | 29.1 | 34.0 | 27.2 | 139.9 | 35.0 |
| | Import share | 0.3% | 6.2% | -6.2% | 8.8% | 37.2% |
| Eastern Europe | 1993 | 40.0 | 27.5 | 18.1 | 208.4 | 208.9 |
| & Central Asia | 2003 | 45.8 | 67.5 | 28.1 | 182.9 | 282.3 |
| | Change | 5.7 | 40.0 | 10.0 | -25.5 | 73.3 |
| | Import share | 10.8% | 30.0% | 35.0% | -38.8% | 28.7% |
| Latin America | 1993 | 26.7 | 56.2 | 13.8 | 132.1 | 141.7 |
| & Caribbean | 2003 | 39.3 | 132.7 | 17.8 | 181.0 | 187.8 |
| | Change | 12.6 | 76.4 | 4.0 | 48.8 | 46.1 |
| | Import share | 5.8% | 18.0% | -65.6% | 22.6% | 7.8% |
| Middle East | 1993 | 15.3 | 26.6 | 11.1 | 61.3 | 77.9 |
| & North Africa | 2003 | 23.9 | 61.8 | 23.3 | 56.9 | 96.3 |
| | Change | 8.6 | 35.1 | 12.2 | -4.5 | 18.4 |
| | Import share | 22.2% | 21.2% | -11.6% | 6.0% | 12.9% |
| South Asia | 1993 | 5.0 | 2.9 | 7.8 | 20.4 | 101.8 |
| | 2003 | 9.9 | 7.4 | 11.1 | 15.5 | 139.4 |
| | Change | 4.9 | 4.5 | 3.4 | -4.9 | 37.6 |
| | Import share | 2.5% | 2.0% | 2.7% | -0.1% | 5.8% |
| Sub-Saharan | 1993 | 6.2 | 9.4 | 15.4 | 58.3 | 39.9 |
| Africa (SSA) | 2003 | 7.2 | 19.3 | 18.2 | 61.8 | 51.0 |
| | Change | 0.9 | 9.9 | 2.8 | 3.5 | 11.1 |
| | Import share | 39.0% | 20.5% | 89.4% | 9.9% | 30.6% |
| All countries | 1993 | 20.5 | 20.2 | 17.3 | 120.0 | 72.8 |
| | 2003 | 32.9 | 45.9 | 29.4 | 162.4 | 107.4 |
| | Change | 12.4 | 25.6 | 12.1 | 42.5 | 34.6 |
| | Import share | 5.0% | 10.7% | 2.4% | 11.1% | 26.6% |

Source: Authors' calculations from FAO (FAO, 2018) data.

**Table A2. Prices of calories from various ASFs in Ghana, Nigeria and Benin relative to calories from the cheapest staple cereal (2011)**

| | Ghana | Nigeria | Benin |
|---|---|---|---|
| Large size chicken eggs | 9.2 | 8.5 | 6.8 |
| Chicken legs | 5.5 | 5.8 | 4.2 |
| | | | |
| Beef, Rump steak | 10.5 | 8.2 | 12.8 |
| Mutton mixed cut | 6.3 | 6.8 | 7.5 |
| Goat mixed cut/with bones | 7.2 | 6.9 | 7.5 |
| | | | |
| Carp | 10.8 | 8.6 | 5.3 |
| Mackerel, un-cleaned | 5.5 | 5.3 | 4.2 |
| Tilapia | 5.0 | 4.2 | 4.1 |
| | | | |
| Milk, powdered | 3.4 | 3.0 | 3.3 |
| Milk, un-skimmed Pasteurized | 14.4 | 13.3 | 14.6 |

Source: Authors' estimates from the International Comparison Program (ICP) data from the World Bank (World-Bank, 2015), and USDA calorie conversion factors (USDA, 2017).

**Table A3. Household expenditure on animal-source food (ASF) items as a share of total ASF expenditure, in poor versus nonpoor households (2017/18)**

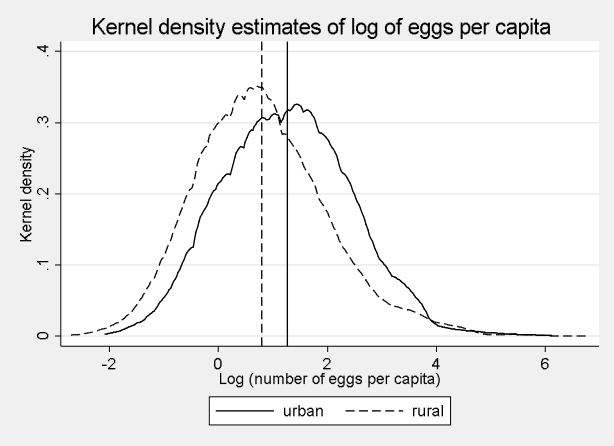
| | Poor households | Nonpoor households |
|---|---|---|
| Eggs | 1.1% | 4.3% |
| Frozen chicken meat | 4.4% | 6.3% |
| Live chickens | 0.8% | 1.7% |
| Processed fish | 70.3% | 54.2% |
| Fresh/frozen fish | 6.4% | 2.7% |
| Dairy | 2.4% | 9.6% |
| Beef | 5.8% | 10.4% |
| Pork | 1.1% | 0.4% |
| Mutton | 0.2% | 0.2% |
| Goat | 1.1% | 1.4% |

Source: Authors' estimates based on Ghana Living Standards Survey round 7 (GLSS7) data.

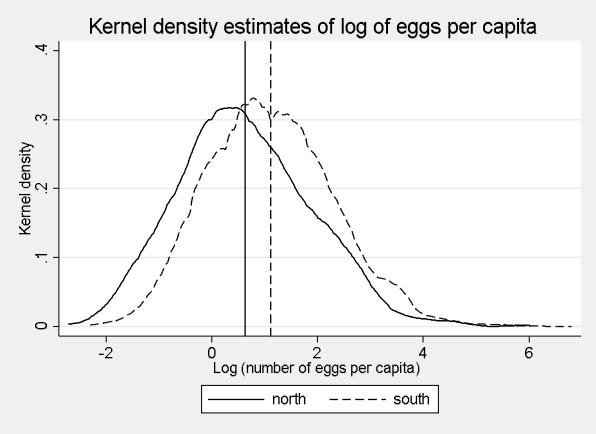
Note: To simplify the figure we exclude expenditure on 'other' animal-source foods outside of these main groups such as corned beef, bushmeat, dog/cat meat, game birds, exotic eggs, and crustaceans.

**Figure A2. Kernel density estimates and means of logs of number of eggs per capita**

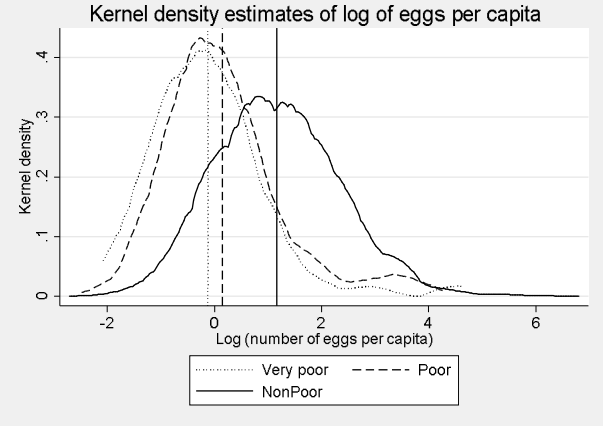
**(a) Urban vs. rural: Log of number of eggs per capita**




**(b) Northern vs. southern Ghana: Log of number of eggs per capita**




**(c) Very poor vs. poor vs. nonpoor: Log of number of eggs per capita**




Source: own estimation based on GLSS7 data (GSS 2018)
Notes: Eggs per capita include the quantity acquired and quantity consumed from own production during each 5-day recall periods measured over 6 visits (30-days total).

**Figure A2. Change in real household consumption from the baseline to the poultry ban scenario (%), by rural and urban consumption quintiles**

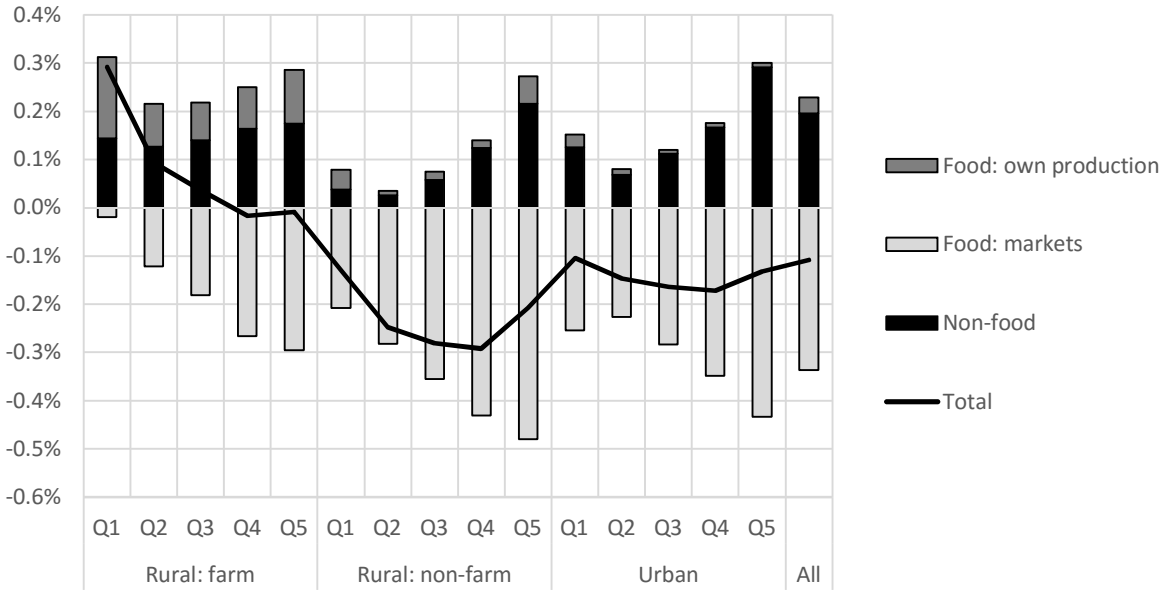


**Table A4. Feed costs in Ghana compared with feed costs in emerging and developed countries**

| | Ghana | Argentina | Brazil | EU | Thailand | USA |
|---|---|---|---|---|---|---|
| Feed price, 2015 (US$/kg) | 0.56 | 0.30 | 0.31 | 0.43 | 0.27 | 0.32 |

Source: Ghana costs are derived from purchase records of the four largest commercial poultry feed companies that are members of the Ghana Feed Millers Association. Costs include yellow maize, soybean, fishmeal, and wheat bran costs for direct feed ingredients, and operating costs (labor, transport, utilities). Costs for Argentina, Brazil, EU, and USA are from Van Horne (2014) and costs for Thailand are from Chokesomritpol, NaRanong, and Kennedy (2018).
Note: For Ghana, feed mills provided egg layer feed costs, while Van Horne reports costs for broiler feed costs for the other countries. To obtain comparable costs the prices for Ghana are adjusted by a factor of 1.2, reflecting the differences reported by Ghana feed mills for broiler versus layer feed mixes.

## Appendix B. Detailed of the Ghana CGE model

We develop a dynamic recursive computable general equilibrium (CGE) model called the Rural Investment and Policy Analysis (RIAPA) model.[10] RIAPA is a variant of the International Food Policy Research Institute (IFPRI) model described in Lofgren et al. (2002) and Thurlow *et al.* (2012). It is a descendant of the class of CGE models introduced by Dervis, de Melo, and Robinson (1982). CGE models, such as RIAPA, are useful for counterfactual analysis as they provide a simulation laboratory of the economy.

The dynamic recursive CGE model used here is based on a 2015 national SAM for Ghana, which is modified to include a more detailed poultry sector. Like a previous application of an economywide model to the poultry sector (Diao, 2009), poultry production is divided between layers, which face essentially no import competition, and broilers, which compete directly with imports of frozen meats. Poultry producers are also split into commercial broilers, commercial layers, and traditional production, and poultry outputs are also disaggregated into commercial and traditional chicken meat and eggs. GDP in Ghana is composed principally of private consumption which accounts for around two thirds of total GDP. Fixed investment and government consumption account for 29% and 17%, respectively; while net trade subtracts from overall GDP. Ghanaian production is concentrated within the services sector which accounts for almost half of total GDP. The agriculture sector is the second largest sector, accounting for almost 20% of GDP. Agricultural value added is concentrated within the crops sub-sectors which accounts for 80% of the sector's total value added. Mining and manufacturing accounts for about 6% of total GDP each and utilities (largely construction) account for 18%. Table B1 presents the structure of the Ghana economy as represented by the 2015 SAM as well as the baseline growth rates used within the CGE model for the 2015-2025 period.

**Table B1. Structure of economy and baseline assumptions**

| | Share of total, 2015 (%) | Baseline average annual growth, 2015-2025 (%) |
|---|---|---|
| **Total GDP** | 100.0 | 5.8 |
| **Private consumption** | 64.6 | 5.4 |
| **Investment** | 28.7 | 7.6 |
| **Government consumption** | 16.5 | 3.5 |
| **Exports** | 30.8 | 5.9 |
| **Imports** | -40.6 | 5.3 |
| **Real exchange rate*** | 1.0 | -0.8 |

**Initial model value, a positive (negative) value indicates an appreciation (depreciation)Source: 2015 Ghana SAM*

[10] A dynamic model accounts for the fact that the poultry sector is currently a relatively small part of Ghana's economy (Diao, 2009).

In the baseline scenario, private consumption remains the key driver of growth. On aggregate, labour supply is assumed to increase more or less in line with population growth (~2 percent per annum), although the supply of skilled labour is assumed to grow at a faster pace than unskilled labour as the education level within the economy rises. Total factor productivity across sectors averages 2.4% per annum. The exchange rate depreciates over the model period as foreign aid to the country decreases.

Behavioural equations in the model capture the decision-making process of agents and allow them to respond to shocks in the system. Structural equations and closure rules ensure macroeconomic consistency between incomes and expenditures within the model and are used to describe the functioning of the economy. These include the behaviour of exchange rates, investment, government savings, and prices and quantities of commodities and factors of production. The dynamic recursive nature of the model allows for an assessment over time as investment is turned into capital endogenously in a putty-clay fashion, meaning that investment in period *t* is turned into capital stock and allocated to sectors in period *t* + 1. The sector capital allocation is determined by the initial share of aggregate capital income, the capital depreciation rate, and period *t* sectoral differentials in rates of return to capital.

In terms of model closures, skilled labor is assumed to be fully employed; wages therefore adjust to changes in demand. Lower skilled labor is characterized by upward sloping supply curves implying that increased supply can be attracted into the labour market through higher wages. Investment is dependent on the level of domestic and foreign savings available in the economy. A floating exchange rate and flexible government balance is assumed in line with the stylized facts for Ghana.

The consumption of eggs has been modelling in the following way:

| | Commercial poultry meat production | Commercial egg production | Traditional poultry meat production | Traditional egg production |
|---|---|---|---|---|
| Rural consumers | 31% | 16% | 100% | 51% |
| Urban consumers | 69% | 84% | 0% | 49% |