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Implications of Avian Flu for Economic Development in Kenya

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ABSTRACT

Kenya is vulnerable to avian flu given its position along migratory bird routes and proximity to other high-risk countries. This raises concerns about the effect an outbreak could have on economic development. We use a dynamic computable general equilibrium model of Kenya to simulate potential outbreaks of different severities, durations, and geographic spreads. Results indicate that even a severe outbreak does not greatly reduce economic growth. It does, however, significantly worsen poverty, because poultry is an important income source for poor farmers and a major food item in consumers' baskets. Avian flu therefore does pose a threat to future development in Kenya. Reducing the duration and geographic spread of an outbreak is found to substantially lower economic losses. However, losses are still incurred when poultry demand falls, even without a confirmed outbreak but only the threat of an outbreak. Our findings support monitoring poultry production and trade, responding rapidly to possible infections, and improving both farmers' and consumers' awareness of avian flu.

Keywords: avian flu, economic growth, poverty, CGE model, Africa

1. INTRODUCTION

The rapid spread of highly pathogenic avian influenza since its emergence in China in 1997 has raised concerns over its potential effect on human well-being and economic development, especially in low-income countries. Outbreaks of avian flu have already been confirmed in parts of Africa. Moreover, although some African countries have not yet experienced outbreaks, they remain vulnerable in terms of both susceptibility and potential economic losses. Kenya is one of these vulnerable countries. Many of its neighbors face a high risk of infection, including southern Sudan, where outbreaks have already occurred. Illegal cross-border trade may facilitate the transmission of the disease to domestic poultry stocks (Omiti and Okuthe 2009). Equally important is the fact that Kenya lies along wild bird migratory routes, which may have caused outbreaks in other countries (see You and Diao 2007). The implications of avian flu for economic growth and poverty are therefore of great concern to countries like Kenya, especially amid considerations of whether or not to devote resources to mitigation efforts.

Besides its detrimental impacts on poultry populations, avian flu is also a serious zoonotic disease affecting humans. By the end of 2009 more than 500 avian flu-related human deaths had been reported by the Food and Agriculture Organization of the United Nations (FAO 2009). This imposes a number of additional costs, including lower productivity and incomes for infected households, medical expenses for those who die and for those who catch the disease but survive, and the extra costs of improving biosecurity for chicken workers (e.g., safety equipment and washing facilities). This transmission of avian flu to humans has heightened awareness about the disease. Indeed, the threat of avian flu has caused many households, including those in Kenya, to limit their consumption of poultry products. Governments such as Kenya's have also banned poultry imports, fearing both human and poultry stock infections (Nyaga 2007; Omiti and Okuthe 2009). Thus, even without a confirmed outbreak, avian flu might undermine the poultry sector with adverse impacts on agricultural livelihoods.

In this paper we estimate the economywide impacts of a potential avian flu outbreak in Kenya. In Section 2 we examine the role of the poultry sector in Kenya's broader economy and for households' livelihoods. Then in Section 3 we develop a dynamic spatial computable general equilibrium (DCGE) model to capture the effects of reduced poultry production and demand on economic growth and poverty. Given the uncertainty surrounding the possible nature of avian flu in Kenya, we design a series of simulations that capture different dimensions of an outbreak, including its severity, duration, and geographic spread. The results from these simulations are presented in Section 4. The final section summarizes our findings and considers their policy implications.

2. ROLE OF POULTRY IN THE KENYAN ECONOMY

Structure of the Economy

Table 1 shows the contributions of different sectors to gross domestic product (GDP) and foreign trade. Agriculture is an important part of the Kenyan economy, accounting for a quarter of total GDP. Food crops form more than half of agricultural production, since maize is the country's main staple. Kenya also has a well-established agricultural export sector (mainly tea, sugarcane, and coffee). Only limited downstream processing of export crops takes place, which explains their high export intensity and the large share of agriculture in total export earnings.

Table 1. Structure of the Kenyan economy

	Share of total (%)				Export intensity	Import intensity
	Total GDP	Agricultural GDP	Exports	Imports		
Total GDP	100.00	-	100.00	100.00	13.26	23.43
Agriculture	25.97	100.00	26.97	4.87	17.38	7.76
Food crops	14.11	54.34	2.89	4.87	3.36	12.09
Export crops	4.62	17.79	23.15	0.00	86.30	0.00
Livestock	5.63	21.68	0.00	0.00	0.00	0.00
Beef & dairy	3.24	12.49	4.46	0.00	0.00	0.00
Poultry	1.30	4.99	1.86	0.00	0.00	0.00
Other livestock	1.09	4.20	1.68	0.00	0.00	0.00
Fisheries	0.47	1.80	0.93	0.00	38.83	0.00
Forestry	1.14	4.39	0.00	0.00	0.00	0.00
Industry	18.02	-	25.27	81.02	10.98	46.07
Mining	0.76	-	2.14	0.00	31.27	0.00
Manufacturing	10.95	-	23.13	81.02	17.00	59.74
Food processing	3.11	-	2.29	9.41	4.37	30.92
Other manufactures	2.57	-	3.96	11.61	18.91	54.56
Other industries	6.31	-	0.00	0.00	0.00	0.00
Services	56.01	-	47.76	14.12	12.95	6.63

Source: Author's calculations using the 2007 Kenyan social accounting matrix (Thurlow 2008).

Note: *Export intensity* is the share of exports in total domestic output. *Import intensity* is the share of imports in total domestic demand.

Livestock generates about 5 percent of total GDP and one-fifth of agricultural GDP. The sector is dominated by cattle and dairy. Poultry, in contrast, is a fairly small subsector, generating 1.3 percent of national GDP. Few livestock products are imported or exported, so in our analysis we assume that poultry is effectively nontraded. This is also consistent with the government's banning of poultry imports following the recent global outbreak of avian flu (Omiti and Okuthe 2009).

Kenya is one of Africa's more industrialized countries, with almost one-fifth of the total GDP generated in the nonmining industrial sector. However, the nonagricultural economy is dominated by services, especially retail trade, transport, and government. Table 2 shows the regional distribution of sectors. Nairobi is clearly the center of Kenya's economy, generating almost one-third of the GDP. Although the capital city does have some agriculture, including poultry, the share is small relative to the metropolitan area's nonagricultural base. Accordingly, in our analysis we will include Nairobi's agriculture as part of the Central province, including those households that rely intensively on farm incomes.

Table 2. Regional structure of the Kenyan economy

	Population (1000s)	Farm population share (%)	Share of national total (%)		
			Total GDP	Agricultural GDP	Poultry GDP
Kenya	35,367	75.78	100.00	100.00	100.00
Central	4,382	83.04	13.15	20.08	15.90
Coast	3,263	61.58	10.17	8.29	17.82
Eastern	5,817	92.70	10.47	18.89	16.28
Nairobi	2,722	-	30.85	-	-
Northeastern	1,106	62.55	0.55	1.62	-
Nyanza	5,053	85.68	11.20	17.72	12.27
Rift Valley	8,690	76.59	18.67	24.30	23.53
Western	4,335	94.21	4.94	9.09	14.20

Source: Author's calculations using the 2005–2006 Integrated Household Budget Survey and the 2007 Kenyan social accounting matrix (Thurlow 2008).

Note: Poultry production is zero in Northeastern and Nairobi provinces because the subsector is a very small share of total production in these regions and therefore is excluded from our analysis.

Poultry and Household Livelihoods

Despite Kenya's large industrial and service sectors, most households depend heavily on agriculture for their livelihoods. Indeed, more than three-fourths of households earn some farm income. Many nonfarm households are also linked to agriculture, such as rural traders and transporters. Poultry plays an important role in the agricultural economy. Kenya has around 34 million chickens, of which four-fifths are indigenous breeds reared in farmers' backyards (Nyaga 2007). Three-quarters of rural farm households keep indigenous chickens, which use little labor time and require few inputs, apart from maize-based animal feeds.

Although backyard production dominates poultry, Kenya also has a large commercial poultry sector, mostly located near the countries' urban centers. These businesses keep large flocks of broilers and layers and produce around 16 million day-old chicks each year. However, compared to indigenous chicken farming, few Kenyans are employed in the commercial poultry sector. This implies that the impact of avian flu on employment and livelihoods is likely to arise via effects on indigenous breeds and locally produced poultry feed. Furthermore, even though the largest commercial poultry company employs a contract system to produce broilers, the farmers involved are large-scale, owning 3,000–12,000 birds per farm (Nyaga 2007). Income changes for these farmers are therefore unlikely to influence poverty. However, income changes might affect national income, and so both backyard and commercial poultry are included in our analysis.

The top part of Table 3 shows that, on average, there are 1.23 birds for each farm household member in Kenya. Per capita poultry ownership is higher among higher-income households, with less than one bird per household member in the lowest quintile and more than two birds per member in the highest quintile. Per capita poultry ownership is highest in the Coastal province.

Table 3. Poultry stocks, incomes, and consumption shares by expenditure quintile

	All farm households	Farm household per capita expenditure quintiles				
		Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Average number of birds per farm household member						
Kenya	1.23	0.89	1.17	1.41	1.37	2.19
Central	1.54	0.87	0.94	0.86	1.86	2.75
Coast	1.87	2.08	2.81	4.38	2.56	5.57
Eastern	1.07	0.67	0.88	1.23	1.23	1.79
Nyanza	1.03	0.47	0.95	1.26	0.99	1.83
Rift Valley	1.25	0.78	1.02	1.59	1.23	1.99
Western	1.23	1.20	1.29	0.89	1.46	1.55
Poultry income share in total farm household income (%)						
Kenya	0.69	2.04	1.89	1.43	0.84	0.23
Central	0.90	1.83	1.31	0.92	1.17	0.67
Coast	2.62	3.65	3.89	3.01	0.91	1.79
Eastern	0.99	1.46	1.21	1.61	1.03	0.47
Nyanza	0.00	0.00	0.00	0.00	0.00	0.00
Rift Valley	0.00	0.00	0.00	0.00	0.00	0.00
Western	0.82	0.86	1.32	1.20	0.53	0.64
Share of poultry in total household consumption expenditure (%)						
Kenya	2.80	2.04	2.84	3.30	3.15	2.67
Central	2.08	1.64	0.23	1.32	1.73	2.54
Coast	3.80	3.71	6.97	5.97	3.59	2.92
Eastern	2.43	0.80	2.24	2.38	3.01	2.54
Nairobi	2.38	0.00	2.76	0.00	0.72	2.49
Northeastern	0.17	0.22	0.71	0.00	0.00	0.00
Nyanza	4.76	3.43	4.01	5.22	6.45	3.99
Rift Valley	1.67	0.69	0.84	1.98	1.25	2.07
Western	6.11	3.39	6.25	6.49	8.03	5.21

Source: Author's calculations using the 2005–2006 Integrated Household Budget Survey and the 2007 Kenyan social accounting matrix (Thurlow 2008).

Note: Farm households include those with and without poultry. Poultry stocks and incomes are zero in Northeastern and Nairobi provinces because the subsector is a very small share of these regions' total production and therefore are excluded from our analysis.

The second part of the table shows the contribution of poultry revenues to total incomes. On average, poultry income generates 0.69 percent of farmers' incomes.¹ Despite their larger poultry ownership, higher-income farmers are, at the national level, less dependent on poultry incomes than lower-income farmers. This is because crop revenues and off-farm earnings become more important income sources as farm incomes rise. Indeed, the contribution of poultry to household incomes in some provinces is highest in the lower and middle parts of the income distribution, thus justifying concerns about the impact of avian flu on household poverty.

The third part of Table 3 shows the shares of poultry in total household consumption expenditure (including the monetary value of home consumption). On average, 2.8 percent of consumer spending is

¹ This is smaller than poultry's contribution to total GDP because the government receives foreign capital (e.g., donor funds), some of which is (directly or indirectly) transferred to households (e.g., pensions and social security).

for poultry and eggs.² This share is highest in the middle of the income distribution and in the Coast, Nyanza, and Western provinces. It is much lower in the Northeastern province, where poultry production is negligible and consumers rely more on other forms of livestock.

In summary, even though the poultry sector is only a small part of the economy, almost all farmers are connected to poultry production, either by rearing backyard chickens, by producing maize for poultry feed, or by consuming poultry products. There is also a large commercial poultry sector that contributes to national income and satisfies most urban areas' consumer demand. However, it is smallholders' livelihoods that are likely to be most affected by avian flu because they rely more heavily on poultry incomes. In the next section we develop an economywide model that captures the structure of the poultry sector and estimates the potential impact of avian flu on national and household-level incomes.

² This is larger than poultry's contribution to total GDP because poultry is nontraded and households use their income for other nonconsumption purposes (e.g., taxes and saving).

3. MODELING THE ECONOMYWIDE IMPACT OF AVIAN FLU

The DCGE model used in this paper captures Kenya's detailed economic structure. This class of economic models is often used to examine external shocks in low-income countries, such as droughts, world price changes, and human and animal illness. The strength of these models is their ability to explicitly measure structural linkages between producers, households, and the government, while also accounting for resource constraints and the role these play in determining product and factor prices. These models do, however, depend on their underlying assumptions and the quality of the data used to calibrate them. This section explains the workings of the Kenyan DCGE model and the data used to calibrate it.

The Core General Equilibrium Model

Table 4 presents the equations of a simple model illustrating how changes in poultry production and demand affect economic growth and household incomes in our analysis. The model is recursive dynamic and therefore can be separated into a static *within-period* component, wherein producers and consumers maximize profits and utility, and a dynamic *between-period* component, wherein the model is updated based on demographic trends and previous period results, thereby reflecting changes in population, labor supply, and the accumulation of capital and technology.

In the static component of the model, producers in each sector s and region r produce a level of output Q in time period t by employing the factors of production F under constant returns to scale (exogenous productivity α) and fixed production technologies (fixed factor shares δ) (equation [1]). Profit maximization implies that factor payments W are equal to average production revenues (equation [2]). Labor and land supply S and capital supply K are fixed within a given time period, implying full employment of factor resources. Land and labor market equilibrium is defined at the regional level, so land and labor is mobile across sectors but wages and rental rates vary by region (equation [6]). National capital market equilibrium implies that capital is mobile across both sectors and regions and earns a national rental rate (i.e., regional capital returns are equalized) (equation [7]).

Factor incomes are distributed to households in each region using fixed income shares based on households' initial factor endowments θ (equation [3]). Total household incomes Y are then either saved (based on marginal propensities to save v) or spent on consumption D (according to marginal budget shares β) (equation [4]). Savings are collected in a national savings pool and used to finance investment demand I (i.e., savings-driven investment closure) (equation [5]). Finally, a single price P equilibrates demand and supply in national product markets, thus avoiding the need to model interregional trade (equation [8]).

The model's variables and parameters are calibrated to observed data from a regional social accounting matrix that captures the initial equilibrium structure of the Kenyan economy in 2007 (Thurlow 2008). Parameters are then adjusted over time to reflect demographic and economic changes, and the model is re-solved for a series of new equilibriums for the eight-year period 2007–2015. Three dynamic adjustments occur between periods: changes in land and labor supply, capital accumulation, and technical change.

Table 4. Simple CGE model equations

Production function	$Q_{srt} = \alpha_{srt} \cdot \prod_f F_{fsrt}^{\delta_{fsr}}$	(1)
Factor payments	$W_{frt} \cdot \sum_s F_{fsrt} = \sum_s \delta_{fsr} \cdot P_{st} \cdot Q_{srt}$	(2)
Household income	$Y_{hrt} = \sum_{fs} \theta_{hf} \cdot W_{frt} \cdot F_{fsrt}$	(3)
Consumption demand	$P_{st} \cdot D_{hsrt} = \beta_{hsr} \cdot (1 - v_{hr}) \cdot Y_{hrt}$	(4)
Investment demand	$P_{st} \cdot I_{st} = \rho_s \cdot \sum_{hr} v_{hr} \cdot Y_{hrt}$	(5)
Labor and land equilibrium	$\sum_s F_{fsrt} = S_{frt}$	<i>f is land and labor</i> (6)
Capital equilibrium	$\sum_{rs} F_{fsrt} = K_{ft}$ and $W_{frt} = W_{fr't}$	<i>f is capital</i> (7)
Product market equilibrium	$\sum_{hr} D_{hsrt} + I_{st} = \sum_r Q_{srt}$	(8)
Labor and land supply	$S_{frt} = S_{frt-1} \cdot (1 + \sigma_{fr})$	<i>f is land and labor</i> (9)
Capital accumulation	$K_{ft} = K_{ft-1} \cdot (1 - \pi) + \sum_s \frac{P_{st-1} \cdot I_{st-1}}{\kappa}$	<i>f is capital</i> (10)
Technical change	$\alpha_{srt} = \alpha_{srt-1} \cdot (1 + \gamma_{srt})$	(11)
<u>Subscripts</u>		<u>Exogenous parameters (continued)</u>
<i>f</i>	Factor groups (land, labor, and capital)	κ Base price per unit of capital stock
<i>h</i>	Household groups	π Capital depreciation rate
<i>r</i>	Regions (provinces)	σ Labor and land supply growth rate
<i>s</i>	Economic sectors	<u>Endogenous variables</u>
<i>t</i>	Time periods	<i>D</i> Household consumption demand quantity
<u>Exogenous parameters</u>		<i>F</i> Factor demand quantity
α	Production shift parameter (factor productivity)	<i>I</i> Investment demand quantity
β	Household average budget share	<i>K</i> National capital supply
δ	Factor input share parameter	<i>S</i> Regional labor and land supply
θ	Household share of factor income	<i>P</i> Commodity price
ρ	Investment commodity expenditure share	<i>Q</i> Output quantity
v	Household marginal propensity to save	<i>W</i> Average factor return
γ	Hicks neutral rate of technical change	<i>Y</i> Total household income

Between periods the model is updated to reflect long-term growth rates in labor and land supply S captured by the parameter σ (equation [9]). For capital supply K , the model endogenously determines the national rate of accumulation (equation [10]). The level of investment I from the previous period is converted into new capital stock using a fixed capital price κ . This is added to previous capital stocks after applying a fixed rate of depreciation π . New capital is endogenously allocated to regions and sectors so as to equalize capital returns. Finally, the model captures total factor productivity through the production function's shift parameter α . The rate of technical change γ is determined exogenously [equation (11)].

Extensions in the Full Kenya DCGE Model

The simple model above illustrates how we link changes in sector production to economic growth and household incomes. However, the full Kenya model drops many of the assumptions implicit in this simplified model (see Lofgren, Harris, and Robinson 2002; Thurlow 2005). Constant elasticity of substitution production functions replace Cobb-Douglas functions in order to allow factor substitution based on relative factor prices (i.e., δ is no longer fixed). The full model identifies 53 sectors (see Table 5), each of which is disaggregated across the country's eight provinces. Intermediate demand in each sector, which was excluded from the simple model, is now determined by fixed technology coefficients (i.e., Leontief). Based on the 2004–2005 Kenya Integrated Household Budget Survey (IHBS), labor markets in each region are further segmented across three skill groups: (1) highly skilled professionals and managers; (2) semiskilled technicians and sales staff; and (3) remaining low-skilled workers, such as farmers. Agricultural land and livestock capital is mobile across sectors within regions but cannot be reallocated to other regions. Poultry capital is separated from other livestock sectors and earns sector-specific returns. Nonagricultural capital is also sector- or region-specific or both. However, new capital from past investment is allocated across regions, sectors, or both according to profit rate differentials under a “putty-clay” specification.

Table 5. Sectors, factors, and regions in the Kenya DCGE model

Agriculture (24)	Maize; wheat; rice; sorghum; millet; cassava; other roots (incl. sweet potatoes); pulses (incl. mixed beans); oil seed crops (incl. sesame, groundnuts); fruits; vegetables; cotton; sugarcane; coffee; tea; tobacco; other crops (incl. pyrethrum); cattle; dairy; poultry; sheep & goats; other livestock (incl. pigs); fisheries; and forestry
Industry (19)	Mining; meat & fish processing; grain milling; sugar processing; other food processing; beverages & tobacco; textiles & clothing; leather & footwear; wood products (excl. furniture); printing & publishing; petroleum products; other chemical products (incl. plastics); non-metallic minerals (incl. glass); metal products (incl. aluminum); machinery; other manufacturing (incl. furniture); electricity; water; and construction
Services (10)	Wholesale & retail trade services; hotels & catering; transport services; communication services; financial services; business & real estate; community & other private services; government administration and services; education; and health
Factors (8)	High-skilled labor; semi-skilled labor; low-skilled labor; agricultural land; agricultural capital; nonagricultural capital; livestock stocks; and poultry stocks
Provinces (8)	Central; Coast; Eastern; Nairobi; Northeastern; Nyanza; Rift Valley; and Western

The full model still assumes national product markets. However, international trade is captured by allowing production and consumption to shift imperfectly between domestic and foreign markets, depending on the relative prices of imports, exports, and domestic goods. Since Kenya is a small economy, world prices are assumed to be fixed and the current account balance is maintained by a flexible real exchange rate (i.e., a price index of tradable-to-nontradable goods). Production and trade elasticities are from Dimaranan (2006).

Households maximize a Stone-Geary utility function such that a linear expenditure system determines consumption with nonunitary income elasticities. Households in each region are disaggregated across farm and nonfarm groups and by per capita expenditure quintiles, giving a total of 75 representative household groupings. These household groups pay taxes to the government based on fixed direct and indirect tax rates. Tax revenues finance exogenous recurrent spending, resulting in an endogenous fiscal deficit. The full Kenya DCGE model captures the detailed sector and labor market structure of Kenya's economy and the linkages between production, employment, and household incomes. The model used in our analysis has already been applied in Kenya (see Thurlow and Benin 2008; Thurlow, Kiringai, and Gautam 2007) and a similar modeling framework was used to address avian flu in Ghana and Nigeria (see Diao 2009; Diao, Alpuerto, and Nwafor 2009).

Avian Flu Simulations

Two consequences of avian flu are captured in the DCGE model. First, an outbreak of avian flu results in the culling of poultry stocks, which reduces the productive capacity of the poultry sector. This production-side shock is captured in the model by reducing poultry capital F (equation [1]) and productivity growth γ for poultry farmers (equation [11]). When poultry production declines in the avian flu simulations, it releases labor to work in other nonpoultry sectors. Falling poultry production will therefore affect household incomes in the model via three channels: (1) direct losses in agricultural revenues for poultry farmers; (2) indirect effects from changes in economywide factor returns; and (3) changes in consumer prices, including that of poultry.

The second consequence of avian flu is reduced consumer demand for poultry products (i.e., poultry meat and eggs). This is captured by reducing the share of disposable incomes that households spend on poultry products (i.e., β in equation [4]) and then increasing demand for nonpoultry products (i.e., manually and proportionally increasing nonpoultry budget shares so that all β 's still total 1).³ The effect of reduced poultry demand on household incomes is not easily predicted, since it is effectively a transfer of demand from one product to another. Poultry farmers will be adversely affected by falling prices and lower returns to their agricultural resources, causing them to shift resources into other activities to offset falling agricultural revenues. This will, however, increase nonpoultry production and reduce nonpoultry products' prices, thus benefiting other household groups in the model. The net effect will depend on the economic structure and income distribution of the Kenyan economy. In our analysis we are able to isolate the effects of production- and demand-side shocks.

There is considerable uncertainty surrounding the scale and nature of a potential avian flu outbreak in Kenya. As shown in Table 6, we run a range of simulations capturing three dimensions of an outbreak: (1) the *severity* of production losses and demand response, (2) the *duration* over which these losses take place, and (3) the geographic *spread* of infected areas. To capture different severities, we model a 15 and 30 percent annual decline in poultry production and demand starting in 2010. For reporting purposes we shall call these *minor* and *major* severities, respectively. These production losses are regionwide outcomes and therefore may include smaller localities where larger shares of the poultry stock are killed as well as other locations within the same broader region where outbreaks have more modest effects. The minor outbreak simulation is similar to outbreaks studied in other countries (Diao 2009; Diao, Alpuerto, and Nwafor 2009; Vanzetti 2007), and the major outbreak simulation can be viewed as an upper bound given other countries' experiences. Since the model does not distinguish between backyard and commercial poultry producers, it is assumed that both types of producers are equally affected by an outbreak.

Table 6. Different dimensions of a simulated avian flu outbreak

Severity (2 levels)	Minor (15 percent annual decline in poultry production and demand) Major (30 percent annual decline in poultry production and demand)
Duration (3 levels)	1 year (2010) 2 years (2010–2011) 3 years (2010–2012)
Spread (3 levels)	Localized (high-risk districts only) Extensive (high- and medium-risk districts) Nationwide (all districts)

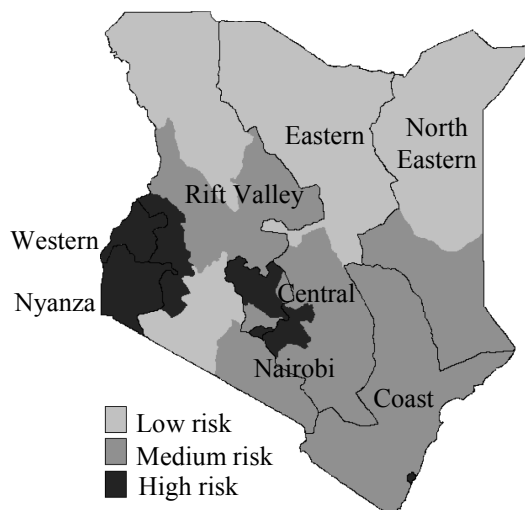
³ All household budget shares of nonpoultry products are adjusted upward in the demand-side simulations. One anonymous reviewer pointed out that it is reasonable to expect that only food products will be affected. However, households spend a majority of their incomes on food products, so most of the adjustment falls on nonpoultry food products. More importantly, the size of the adjustment is small after the fall in poultry demand is distributed across all households on nonpoultry products. Thus the assumption that adjustments are distributed across food and nonfood products does not greatly influence the model results nor the conclusions of the paper.

Secondly, the duration over which annual declines take place varies from one to three years (i.e., 2010, 2010–2011, and 2010–2012). During these outbreaks of different durations, poultry production and demand declines by either 15 or 30 percent each year, thus compounding economic losses. The effects of the production losses, however, last longer than the outbreak period. More specifically, poultry stocks do not return to predisease levels following an outbreak, and farmers will take time to accumulate new poultry stocks. This captures the long-term effects of avian flu on poultry stocks and the possibility that avian flu may become a component of the portfolio of animal diseases that Kenyan farmers face. Together, there are six possible combinations of simulations based on different severities and durations of a potential outbreak.

Finally, a third dimension of an outbreak is its geographic spread. Different parts of Kenya have different vulnerabilities to avian flu based on, for example, their proximity to migratory bird routes or neighboring countries. This is captured by a district-level avian flu risk index estimated by Stevens et al. (2009) (see Figure 1). To capture different spreads of an outbreak, we run each of the six severity and duration combinations assuming (1) a localized outbreak only in high-risk districts, (2) a more extensive outbreak covering both high- and medium-risk districts, and (3) a nationwide outbreak covering all districts. Since the DCGE model is disaggregated by province, we weighted poultry production shocks by district-level populations to derive province-level shocks.

In summary, the DCGE model captures the economywide impact of a potential avian flu outbreak, including its effect on both economic growth and household incomes. The model is calibrated to the most recent social accounting matrix and household budget survey and captures the detailed economic structure of the Kenyan economy. Finally, since it is impossible to predict the actual severity, duration, and spread of a potential outbreak, we run a number of simulations in our analysis to estimate economic losses across a wide range of possible outbreak scenarios.

Figure 1. District-level avian flu risk index



Source: Author's calculations using the avian flu risk index from Stevens et al. (2009).

Note: Minimum-risk indexes are used in the figure. Low-risk index values range from 80 to 100; medium-risk, from 100 to 120; and high-risk, from 120 to 140.

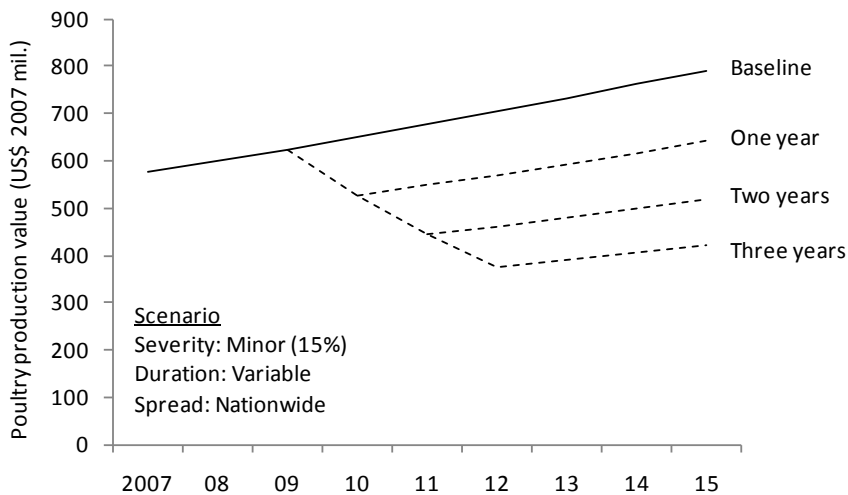
4. SIMULATION RESULTS

To estimate the economic impact of avian flu, we first simulate a baseline scenario without an outbreak. This baseline scenario draws on recent growth and demographic trends. We assume that labor supply, population, and agricultural land expand at 2 percent per year during 2007–2015. Poultry and nonpoultry livestock stocks also grow at 2 percent annually. Agricultural and nonagricultural total factor productivity grow at 1 and 3 percent, respectively, thus reflecting weaker agricultural production in recent years (see Thurlow and Benin 2008). With these assumptions, total GDP growth averages about 5 percent per year. It should be noted that the baseline only provides us with a counterfactual and therefore does not influence our conclusions. Starting from this baseline, we reduce poultry production and demand in order to simulate an avian flu outbreak of varying dimensions.

Different Dimensions of an Outbreak

To account for uncertainty, we model outbreaks that vary in severity, duration, and spread (see Table 6). To illustrate these dimensions we first report the impact of avian flu on the real value of poultry production. Figure 2 shows the impact of a minor nationwide outbreak of different durations (i.e., one that reduces poultry production and demand by 15 percent each year). In the baseline scenario, poultry production continues to grow throughout the 2007–2015 period. However, in the one-year duration scenario, production falls in 2010. Production then grows again in subsequent years, albeit from a lower base. This reflects the culling of poultry stocks and the recovery period after an outbreak. In the two- and three-year duration scenarios, production continues to fall until 2011 and 2012, respectively. Thus the decline in poultry stocks and production is significantly larger when the duration of an outbreak is lengthened.

Figure 2. Poultry production under avian flu scenarios with variable durations



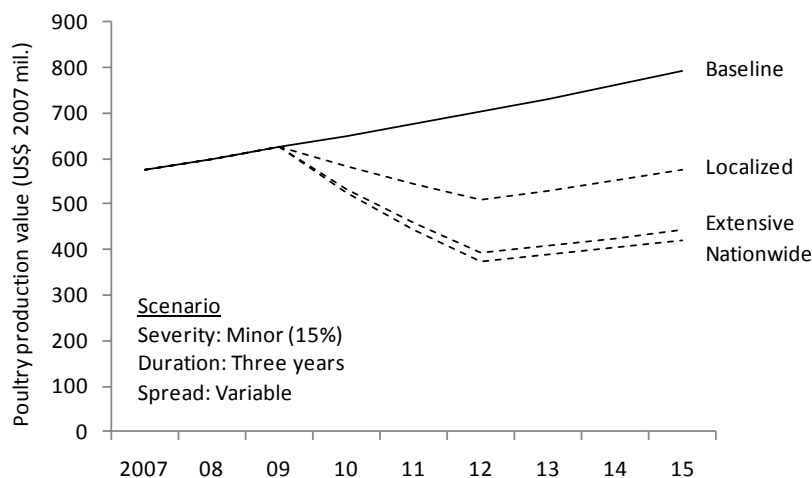
Source: Results from the Kenya DCGE and microsimulation models.

Notes: Impact of the combined production and demand scenario on the real value of poultry production (measured in 2007 prices).

Figure 3 also shows the impact of a minor outbreak. However, in this figure we vary the geographic spread rather than the duration, which we fix at three years. In a localized outbreak, only certain areas of the country are affected, including all of the Nyanza and Western provinces and most of the Central province (i.e., the high-risk districts shown in Figure 1). Even though avian flu is concentrated

during a localized outbreak, the fall in poultry production is still significant because the affected districts account for about half of national poultry production (see Table 2). Production losses are larger in an extensive outbreak, which also includes the Coast province and large portions of the remaining provinces (i.e., both high- and medium-risk districts). Finally, only a small additional loss is incurred when an extensive outbreak becomes nationwide, because none of the low-risk districts are major poultry producing areas (i.e., the northern parts of the Rift Valley and Northeast provinces).

Figure 3. Poultry production under avian flu scenarios with variable geographic spreads



Source: Results from the Kenya DCGE and microsimulation models.

Notes: Impact of the combined production and demand scenario on the real value of poultry production (measured in 2007 prices).

Figures 2 and 3 underline the uncertainty surrounding a potential avian flu outbreak. Table 7 summarizes the impact on poultry production for all dimensions of an outbreak. As was shown in Figure 2, a one-year nationwide outbreak reduces total poultry production by between 19.0 and 36.5 percent, depending on its severity. It should be noted that the overall impact is larger than the separate production- or demand-side shocks because these compound each other, causing poultry production to fall by more than 15 or 30 percent in a minor or major outbreak, respectively. Similarly, lengthening the duration of an outbreak leads to less-than-proportional reductions in production, since the *absolute* size of the percentage-based shocks becomes smaller in subsequent years. However, the model results clearly indicate that increasing the severity, duration, and geographic spread of an outbreak leads to significantly larger declines in poultry production. This underlines the importance of responding rapidly to an outbreak in order to limit transmission of the disease to other farmers and provinces.

Table 7. Deviation in national poultry production from baseline in 2015 (%)

Severity of outbreak	Spread of outbreak	Duration of outbreak		
		One year	Two years	Three years
Minor (15%)	Localized	-10.51	-19.61	-27.52
	Extensive	-17.72	-32.27	-44.22
	Nationwide	-18.97	-34.34	-46.80
Major (30%)	Localized	-20.46	-35.61	-47.04
	Extensive	-34.15	-56.52	-71.21
	Nationwide	-36.47	-59.64	-74.36

Source: Results from the Kenya DCGE and microsimulation models.

Notes: Impact of the combined production and demand scenario on the real value of poultry production (measured in 2007 prices).

Economywide Losses and Growth Effects

The previous section presented the direct impact of avian flu on poultry production. However, an outbreak will also affect nonpoultry sectors via a number of transmission channels. For example, declining production will reduce poultry farmers' incomes and hence their demand for nonpoultry consumer products. Similarly, by reducing the number of flocks, avian flu will lower upstream demand for animal feeds, thereby affecting maize farmers. Conversely, when poultry stocks are culled, poultry farmers will reallocate productive resources (i.e., labor) to nonpoultry activities, such as crop farming and off-farm employment. As a result, avian flu may actually expand production in nonpoultry sectors. It is necessary to account for all indirect sector linkages and factor market adjustments when estimating economywide losses.

Table 8 reports estimated losses in total GDP caused by outbreaks of different dimensions. The DCGE model estimates that a minor one-year localized outbreak reduces total baseline GDP by US\$39 million (measured in 2007 prices). These losses increase under lengthier and more severe outbreaks. For instance, a major three-year nationwide outbreak generates economywide losses of US\$248 million. It is worth noting that the estimated losses are measured only after the economy has had time to adjust. This implies that farmers have had sufficient time to reallocate resources to nonpoultry sectors and that laborers in commercial poultry businesses have had sufficient time to find new jobs. In reality, there may be a short-term adjustment period following an outbreak. However, since very little labor is used for backyard poultry rearing, and since this is where most of the economic losses occur, it is likely that any adjustment costs will be small compared to the medium-term losses reported in the table.

Table 8. Total economic losses due to avian flu (US\$ million)

Severity of outbreak	Spread of outbreak	Duration of outbreak		
		One year	Two years	Three years
Minor (15%)	Localized	-38.7	-71.4	-99.0
	Extensive	-61.4	-111.1	-151.3
	Nationwide	-65.2	-117.3	-158.9
Major (30%)	Localized	-76.0	-130.8	-170.8
	Extensive	-118.8	-194.6	-241.6
	Nationwide	-125.7	-203.0	-248.4

Source: Results from the Kenya DCGE and microsimulation models.

Notes: Impact of the combined production and demand scenario on the real value of total GDP in 2015 (measured in 2007 prices).

Economic losses are not evenly distributed across provinces. This is evident in Table 9, which reports changes in provincial GDP following a three-year avian flu outbreak. Not surprisingly, the province facing the largest economic losses varies according to the geographic spread of the outbreak. In a localized outbreak, the largest losses occur in the high-risk Nyanza, Western, and Central provinces. The Rift Valley also experiences large losses despite being at a more moderate risk level. This is because the Rift Valley is a large province and a significant share of its population resides in high-risk districts (see Figure 1). In contrast, the Eastern province is largely unaffected by a localized outbreak since none of this province's districts are at high risk. However, large losses are experienced in this province during an extensive outbreak, when medium-risk districts are affected. Finally, Nairobi benefits slightly from an avian flu outbreak. This is primarily because falling demand for poultry leads to some increase in demand for nonfood products, which benefits Nairobi's large nonagricultural economy (see Table 2).

Table 9. Total economic losses due to a three-year avian flu outbreak (US\$ million)

	Minor outbreak (15%)			Major outbreak (30%)		
	Localized	Extensive	Nationwide	Localized	Extensive	Nationwide
Kenya	-99.0	-151.3	-158.9	-170.85	-241.64	-248.42
Central	-19.7	-25.3	-24.9	-33.74	-39.43	-38.40
Coast	-8.8	-29.9	-29.6	-17.05	-47.17	-46.51
Eastern	-1.9	-20.6	-21.4	-4.91	-32.82	-33.46
Nairobi	-1.5	0.9	1.4	-3.22	0.21	0.65
Northeastern	0.1	0.0	0.0	0.13	-0.15	-0.27
Nyanza	-19.6	-17.8	-17.3	-31.47	-27.14	-25.80
Rift Valley	-21.6	-33.7	-42.5	-39.41	-56.98	-67.33
Western	-26.0	-24.8	-24.6	-41.17	-38.17	-37.30

Source: Results from the Kenya DCGE and microsimulation models.

Notes: Impact of the combined production and demand scenario on the real value of total GDP in 2015 (measured in 2007 prices).

In summary, avian flu could cost the Kenyan economy between US\$38 and US\$248 million, depending on the scale and duration of an outbreak. However, these impacts remain very small relative to the overall size of the economy. For instance, even a major three-year nationwide outbreak would only reduce the country's average annual total GDP growth rate by 0.12 percentage points during 2009–2015. Thus, although potential economic losses caused by avian flu are significant, it is unlikely that an outbreak would have a severe detrimental effect on economic growth in Kenya.

Household Welfare and Poverty Effects

Even though the impact of avian flu on national income is small, it has large negative consequences at the household level, especially among certain population groups. Table 10 reports changes in average annual per capita growth in equivalent variation, which is a household welfare measure that controls for changes in prices. As mentioned above, a major three-year nationwide outbreak reduces the national GDP growth rate by only 0.12 percentage points per year. However, the impact on per capita equivalent variation growth is larger, at 0.41 percentage points (see the top part of Table 10). This is because poultry contributes a larger share to household incomes than it does to national GDP (see Tables 1 and 3). Welfare losses are also larger for farm households, although these losses also vary considerably depending on the scale and duration of an outbreak.

Table 10. Deviation in average annual per capita equivalent variation from baseline due to avian flu (% point)

Severity of outbreak	Spread of Outbreak	Duration of outbreak		
		One year	Two years	Three years
All households				
Minor (15%)	Localized	-0.02	-0.04	-0.06
	Extensive	-0.04	-0.09	-0.14
	Nationwide	-0.05	-0.10	-0.16
Major (30%)	Localized	-0.04	-0.08	-0.11
	Extensive	-0.09	-0.21	-0.35
	Nationwide	-0.11	-0.24	-0.41
Farm households				
Minor (15%)	Localized	-0.04	-0.08	-0.11
	Extensive	-0.07	-0.14	-0.21
	Nationwide	-0.07	-0.15	-0.23
Major (30%)	Localized	-0.08	-0.15	-0.20
	Extensive	-0.15	-0.30	-0.47
	Nationwide	-0.16	-0.33	-0.54

Table 10. Continued

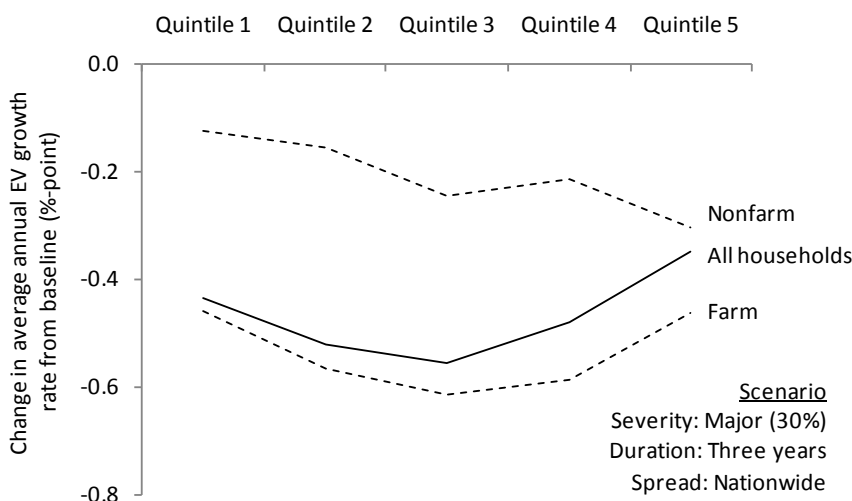
Severity of outbreak	Spread of Outbreak	Duration of outbreak		
		One year	Two years	Three years
		Nonfarm households		
Minor (15%)	Localized	0.00	0.00	0.00
	Extensive	-0.02	-0.04	-0.07
	Nationwide	-0.02	-0.05	-0.09
Major (30%)	Localized	0.00	0.00	-0.01
	Extensive	-0.04	-0.11	-0.23
	Nationwide	-0.05	-0.14	-0.29

Source: Results from the Kenya DCGE and microsimulation models.

Notes: Impact of the combined production and demand scenario on households' real annual equivalent variation growth rate during 2009–2015. *Equivalent variation* is a welfare measure controlling for changes in prices.

Avian flu affects Kenya's income distribution. Figure 4 shows the impact of a major three-year nationwide outbreak on household welfare across per capita expenditure quintiles. The solid, curved line in the figure indicates that households in the middle of the income distribution (i.e., quintile 3) are most vulnerable to welfare losses caused by avian flu. This is because these households are most reliant on poultry incomes (see middle part of Table 3). In contrast, higher-income nonfarm households are more affected than lower-income nonfarm households because they spend a larger share of their disposable incomes on poultry products (see bottom part of Table 3). However, despite these distributional variations, the model results indicate that all income quintiles and both farm and nonfarm households would be adversely affected by an avian flu outbreak.

Figure 4. Deviation in national household equivalent variation by expenditure quintile



Source: Results from the Kenya DCGE and microsimulation models.

Notes: Equivalent variation is a welfare measure controlling for prices.

The DCGE model is linked top-down to the 2005–2006 household survey. This means that changes in real per capita consumption for each household group in the model are passed down to their corresponding households in the survey, where poverty is calculated. This is the *microsimulation* component of the model. Table 11 reports changes in the final-year poverty headcount rate from the

baseline scenario caused by avian flu.⁴ In a major three-year nationwide outbreak the national poverty headcount increases by 1.15 percentage points. This reflects the welfare losses experienced by households near the poverty line (i.e., quintile 2 in Figure 4). Given a 2 percent annual population increase, Kenya's total population is projected to reach 41.4 million people by 2015. Thus, the increase in the final-year poverty rate by 1.15 percentage points is equivalent to an additional 478,000 people living below the poverty line as a result of a severe and lengthy outbreak of avian flu (see bottom part of Table 11). Thus, although avian flu would only have a small detrimental effect on national economic growth, its implications for household welfare and poverty could be far more pronounced.

Table 11. Deviation in household poverty due to avian flu

Severity of outbreak	Spread of outbreak	Duration of outbreak		
		One year	Two years	Three years
Deviation in national poverty headcount rate from baseline in 2015 (% point)				
Minor (15%)	Localized	0.18	0.37	0.54
	Extensive	0.23	0.49	0.64
	Nationwide	0.27	0.52	0.64
Major (30%)	Localized	0.40	0.76	0.90
	Extensive	0.50	0.92	1.10
	Nationwide	0.58	0.93	1.15
Deviation in national poor population from baseline in 2015 (in 1000s of people)				
Minor (15%)	Localized	74.4	154.0	224.8
	Extensive	95.0	201.9	264.7
	Nationwide	112.9	214.3	264.2
Major (30%)	Localized	165.0	314.4	373.6
	Extensive	206.4	381.6	456.0
	Nationwide	241.7	385.3	477.8

Source: Results from the Kenya DCGE and microsimulation model.

Notes: Initial poverty rates calculated using the 2005–2006 Kenya Integrated Household Budget Survey.

Production versus Demand Shocks

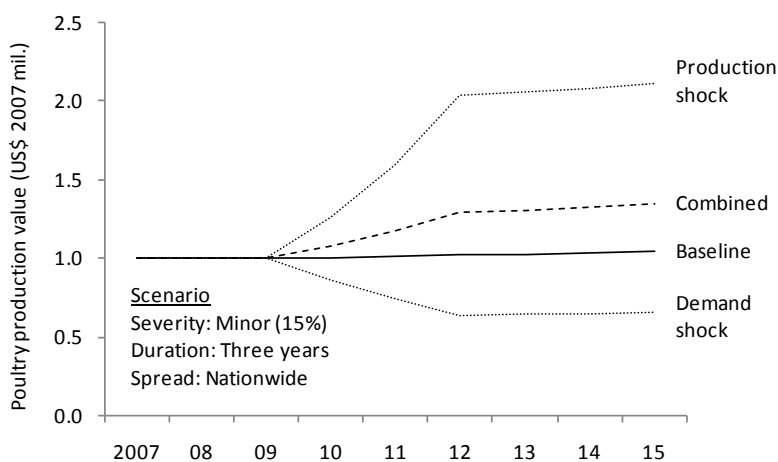
The simulations reported above include both production- and demand-side effects of avian flu. However, as Kenya experienced in 2005, it is possible that households will respond to the threat of avian flu by reducing their demand for poultry products even if an outbreak has not been confirmed (Kimani et al. 2006). A fall in demand for poultry products produces outcomes different from those reported earlier. Figure 5 decomposes changes in poultry market prices caused by production- and demand-side shocks. Reducing production without lowering demand causes *real* poultry prices to double in a minor three-year nationwide outbreak. Conversely, reducing demand without culling birds causes an oversupply of poultry products and falling market prices. Lower prices benefit those consumers who continue to eat poultry despite the threat of avian flu. It will, however, reduce agricultural revenues for poultry farmers.

Table 12 reports economywide losses for outbreaks of different dimensions. Total GDP falls by far less when only poultry demand falls during an unconfirmed outbreak (i.e., when farmers do not cull poultry stocks). For example, demand-side shocks cause economywide costs equal to US\$52 million during a major three-year nationwide outbreak. This is much lower than the US\$163 million production-side cost incurred during a similar outbreak. This suggests that solely demand-side shocks generate costs equal to about one-quarter of the total costs estimated in the combined scenarios reported earlier. These

⁴ The poverty headcount is the share of Kenya's total population with per capita consumption levels below the national poverty line. In 2005–2006, 47 percent of Kenya's population were classified as *poor*. This falls to 35 percent by 2015 in our modeled baseline scenario, which projects real per capita GDP growth of around 3 percent per year.

decomposed results clearly indicate that significant economic losses are still incurred if consumers respond to the *threat* of avian flu even if an outbreak has not actually occurred.

Figure 5. Poultry prices under production- and demand-driven avian flu scenarios



Source: Results from the Kenya DCGE and microsimulation models.

Table 12. Total economic losses due to production- and demand-side avian flu shocks (US\$ million)

Severity of outbreak	Spread of outbreak	Duration of outbreak		
		One year	Two years	Three years
Production-side shocks only				
Minor (15%)	Localized	-28.4	-53.7	-76.7
	Extensive	-46.8	-85.3	-117.4
	Nationwide	-49.9	-90.2	-123.1
Major (30%)	Localized	-54.5	-95.1	-126.6
	Extensive	-87.0	-136.9	-163.4
	Nationwide	-92.1	-141.0	-163.3
Demand-side shocks only				
Minor (15%)	Localized	-10.1	-16.8	-20.9
	Extensive	-13.8	-22.9	-28.4
	Nationwide	-14.3	-23.8	-29.5
Major (30%)	Localized	-20.2	-31.9	-38.0
	Extensive	-27.7	-43.0	-50.8
	Nationwide	-28.8	-44.6	-52.4

Source: Results from the Kenya DCGE and microsimulation models.

Notes: Impact on the real value of total GDP in 2015 (measured in 2007 prices).

5. CONCLUSIONS

Although there has not been an outbreak of avian flu in Kenya, the country still remains vulnerable to the disease due to its position along migratory bird routes and its proximity to other high-risk countries. This raises concerns over the effects that an outbreak could have on economic development. In this study we estimated the implications of avian flu for economic growth and poverty in Kenya. We developed a DCGE model that captures the detailed structure of the Kenyan economy. Given the uncertainty about the nature of avian flu, we simulated outbreaks of different severities, durations, and geographic spreads. We also decomposed avian flu effects in order to capture possible demand-side responses to the threat of the disease even if an outbreak does not actually occur.

Model results indicate that the economywide costs of a severe and lengthy outbreak could be as high as US\$248 million (measured in 2007 prices). Although this is a substantial economic loss, it is small relative to total national income. Thus, even a severe outbreak of avian flu would not have a large detrimental effect on economic growth. It would, however, have a significant impact on household welfare and poverty. Model results indicate that a severe and prolonged outbreak could increase the number of people living below the poverty line by almost half a million. This would be a major setback for Kenya, where almost half of the population is already considered poor, and where economic growth has so far failed to significantly reduce poverty (Thurlow, Kiringai, and Gautam 2007). In this regard, avian flu does represent a significant threat to future development in Kenya.

Model results indicate that economic losses from avian flu are substantially lower when an outbreak remains localized in high-risk districts and when its duration is kept short. This suggests that if an outbreak occurs, the government and its development partners should respond rapidly to limit the transmission of the disease to farmers in lower-risk areas. However, results also indicate that one-quarter of the economywide losses of an actual severe and lengthy outbreak are still incurred when consumer demand for poultry products falls in response to an unrealized outbreak. Thus, even without a confirmed outbreak, Kenya is still vulnerable to the threat of avian flu and its effect on consumer behavior. Together our findings underline the importance of ongoing efforts to monitor cross-border poultry trade, to undertake rapid testing of possible infections, to regulate the disposal of infected birds, and to improve both farmers' and consumers' awareness of avian flu. Although these measures cannot ensure that an outbreak would not occur, they can greatly reduce the threat that avian flu poses to future development in Kenya.

There are two main limitations to the analysis where further work may be warranted. First, we focused exclusively on the impact of avian flu on the poultry population and did not consider additional impacts if the disease were to be transmitted to humans. While this may not have large economywide implications—given the low mortality rates experienced in other countries—it could impose significant welfare losses for households with infected members. Secondly, the model simulations focused on the impact of an avian flu outbreak without considering concurrent mitigation policies or investments. Experiences in Thailand, Vietnam, and Indonesia show that vaccination programs, certification of day-old chicks, and shed biosecurity measures (e.g., footbaths) can effectively reduce poultry losses. Thus, the analysis in this paper highlights the need for mitigation efforts, but it does not attempt to model the effects that public sector policies and investments will have in offsetting the economic losses caused by avian flu.

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