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SUPPLEMENT ARTICLE

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Modelling policies to improve affordability and consumption of nutritious foods for complementary feeding in Kenya

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Abstract

In Kenya 26% of children under age 5 experience stunted growth, 4% are wasted and 11% are underweight. In pregnant women, the prevalence of iron deficiency is 36% and iron-deficiency anaemia prevalence is 26%. Previous studies have identified affordability as a key barrier to the intake of nutrients, particularly from animal-source foods (ASFs). Thus, this study analyzes to what extent the affordability of ASF in Kenya can be improved. It focuses on four ASFs: eggs, milk, chicken and beef. Using a computable general equilibrium model, three policy simulations were undertaken to establish the impact of potential changes on nutritious ASF availability and affordability: a 20% increase in total factor productivity (TFP) for the four products; a 20% TFP increase plus a 25% reduction in trade and transportation margins; and a 20% TFP increase for ASF and maize (a key input in animal feed). Simulations suggest increasing the productivity of the four ASF products would increase their availability and lower consumer prices (up to 17% lower). Household consumption of the four commodities would increase, resulting in improved household dietary diversity. Rural households would gain more compared with urban households. Poor households (the lowest 40%) would register larger welfare (Equivalent Variation) gains than other households in both urban and rural areas. The richest 20% of the population would neither lose nor gain following the policy changes. Reducing transportation costs and trade margins and increasing maize productivity could further reduce the price of ASFs through lower production costs and increased consumption.

KEYWORDS

affordability, animal-source foods, availability, dietary diversity, Kenya, nutrient deficiencies, welfare

1 | INTRODUCTION

According to the latest welfare report of the Kenya National Bureau of Statistics (KNBS, 2018), 32% of adults experienced food poverty, and 8% of adults were extremely poor. There was a remarkable difference between rural and urban areas, with food poverty rates (people living below the 2100 kcal/adult/day threshold) of 35%, 24% and 28% for rural, core-urban and peri-urban areas, respectively. Moreover, the food poverty prevalence among children aged 0–17 years was 36%. The chronically food insecure also suffered from extreme poverty, with no social safety net programmes to protect them in emergency situations, illustrating the inextricable link between poverty and food insecurity.

While considerable progress has been made, Kenya still faces high levels of malnutrition. According to child health statistics at the national level, 26% of children under 5 years of age were stunted, 4% were wasted and 11% were underweight (KNBS, 2014). This impaired growth is a predictor of poorer survival and increases the risk of obesity and diet-related noncommunicable diseases in adulthood. Moreover, it can worsen cognitive and educational outcomes, eventually leading to loss of income and employment opportunities in adult life (United Nations Children's Fund [UNICEF], 2020).

Micronutrient deficiencies are also highly prevalent in Kenya, especially among children under the age of 5 years: the prevalence of vitamin A deficiency is 9%, that of iron deficiency is 22% and that of zinc deficiency is 83% (Kenya Medical Research Institute et al., 2011). Global Alliance for Improved Nutrition (GAIN) and UNICEF (2021) provide further evidence that young children in Kenya (aged 6–23 months) face clear dietary gaps in iron and zinc and potential gaps in calcium, vitamin B_{12}, folate and vitamin A; such micronutrient deficiencies during the complementary feeding period can hinder health, growth and development (GAIN & UNICEF, 2021). Women, especially pregnant women, are also vulnerable to micronutrient malnutrition. Iron deficiency anaemia affects 26% of pregnant women and 14% of nonpregnant women (Kenya Medical Research Institute et al., 2011). Analysis by Marivoet et al. (2020) also suggests the prevalence of household dietary micronutrient inadequacies is very high across population groups.

One of the key factors driving these inadequacies is likely to be an inadequate intake of animal-source foods (ASFs), which tend to be nutrient dense and particularly rich in micronutrients such koas iron, zinc, calcium, vitamin B_{12} and vitamin A (KNBS, 2014; Murphy & Allen, 2003; Nordhagen et al., 2020). One of the key barriers, in turn, to the consumption of ASF is their relative cost: in lower-income countries such as Kenya, ASF tend to be considerably more expensive than alternatives such as cereals (Headey & Alderman, 2019). When considering affordability in terms of nutrient density, Ryckman et al. (2022, this supplement) found that food sources with adequate amounts of vitamin A, B_{12} and folate were affordable to most Kenyan households, whereas food sources with adequate amounts of iron, calcium, zinc and animal-source protein were not. Small dried fish and liver were particularly affordable ASFs in terms of nutrient content provided per unit price. Finally, Marivoet et al. (2020) found that unaffordability of micronutrients such as iron and zinc was partly because they are often found in their densest and most bioavailable forms in ASF, which tend to be comparatively expensive.

Key messages

- Affordability is a key barrier to the consumption of nutritious animal-source foods (ASFs) in Kenya.
- We undertook simulations to understand how policy changes would impact ASF affordability and availability.
- Increasing the supply of ASFs could yield lower prices for these foods.
- The impact on prices could be magnified if supply increases were accompanied by reduced trade and transportation margins.
- Intake of ASFs and dietary diversity could increase if prices were lowered.

Increasing the affordability of ASF is therefore a key element when designing policies to reduce nutrient deficiencies and achieve food and nutrition security (GAIN, 2016; Marivoet et al., 2020; GAIN & UNICEF, 2021). Thus, the overall objective of this study was to identify various means of improving the affordability of ASF through increased availability and accompanying policies to reduce transaction costs between producers and consumers. The targeted foods were eggs, milk, chicken and beef. It was expected that greater availability and lower transaction costs would improve affordability for resource-constrained households through lower consumer prices and higher producer prices (i.e., higher incomes for households that raise animals).

We achieved this objective by simulating a series of policy scenarios aimed at increasing the affordability of ASF through increased productivity of the animal products sector and reduced trade and transportation margins. To do this, we used a dynamic computable general equilibrium (CGE) model of the Kenyan economy calibrated to a 2018 Social Accounting Matrix (SAM). Our approach expands on previous studies (Ramos et al., 2021) by looking at the production level of the supply chain. As outcomes, we consider availability, price, consumption and welfare (as measured by 'Equivalent Variation (EV) in income', explained in the next section).

2 | METHODS

2.1 | The modelling approach

The methodology used builds on the circular flow of the economy (Lofgren et al., 2002), which is a concept used to understand how the economy works as a whole. It captures the behaviour of economic agents (households, governments, firms and the rest of the world) through the transfers (payments) they make among themselves and in the various sectors of the economy (Supporting Information: Figure 1). For production to take place, inputs for land, labour and capital must be used. These are obtained through purchase from markets where they are sold (factor markets). The value added from primary factors (labour, land and capital) is combined with intermediate inputs from the commodity markets to produce goods and services. Locally produced and imported goods are sold to households, governments or investors, or are exported. In the circular flow of the economy, one institution's expenditure is another institution's revenue.

The specific model used to examine this circular flow is a CGE model similar to the International Food Policy Research Institute (IFPRI) standard model (Lofgren et al., 2002). A CGE model was required given the size of the shocks being simulated (countrywide shocks) and the need to consider the interdependencies (upstream and downstream) between sectors (supply side), substitution and income effects (demand side), as well as resources and macroeconomic constraints (e.g., current account balance, fiscal constraints). For instance, a policy to increase domestic supply will reduce imports and impact the country's current account balance. The standard IFPRI model was further adjusted to make it dynamic. A 5-year period was examined, from 2020 to 2025.

The following assumptions were made in the model: (i) labour is mobile, while land and capital are specific to sectors, (ii) the current account balance and government savings are fixed to avoid artificial welfare increases and (iii) investment is driven by savings. The focus commodities for this study were (beef) meat, milk, eggs and chicken.

Once the model was calibrated (replication of the base year, 2018), we built a baseline (reference scenario), which does not include any policy change. We then introduced the policy changes and compared the results between the scenario simulated and the baseline. Supporting Information: Figure 2 summarizes the different steps of the process.

Guided by previous work by Marivoet et al. (2020) and Ramos et al. (2021) on the obstacles to affordability and the potential gains in reducing transaction costs, three simulations (Sim) were undertaken:

1. Sim 1: 20% total factor productivity (TFP) increase on all focus ASF commodities (eggs, milk, chicken and beef).
   Given the inelastic nature of supply and demand, it is expected that the increase in availability through more supply would put more pressure and yield lower prices and make ASF more affordable.
2. Sim 2: 20% TFP increase on all focus ASF commodities + 25% reduction in trade and transportation margins.
   We expected here larger price falls as margins were reduced, in addition to more supply.
3. Sim 3: 20% TFP increase on all focus ASF commodities + 20% productivity increase in the maize sector, with maize being a key input in animal feed.
   We expected here lower prices for maize and thus lower prices for ASF as production costs would fall.

Changes in policy impact food prices and household consumption of foods and, consequently, dietary diversity. Dietary diversity is identified as a key element of high-quality diets and increases the likelihood of achieving nutrient adequacy (Rathnayake et al., 2012). The effect on dietary diversity was assessed using the Dietary Diversity Score (DDS), a quantitative measure used to establish the extent to which households access a variety of foods. The DDS was calculated here using the Shannon entropy index as shown in the equation below:

$$\text{DDS} = \sum_{i=1}^{n} w_i \times \log\left(\frac{1}{w_i}\right),$$

where w_i: share of food group i.

Higher entropy values imply greater dietary diversity and the score ranges from log (n) when consumption shares are equally distributed among different food categories to 0 when only one food group is consumed. We considered six food groups in our analysis: cereals, roots, fruits and vegetables, legumes, ASFs and other products, so the index ranges from 0 to log (6) (i.e., 1.79).

The DDS index calculated using the Shannon entropy value is more relevant for this analysis than the traditional Household Dietary Diversity Score, which is computed by summing the number of food groups consumed in the household or by the individual respondent over a given recall period (Kennedy et al., 2011). Unlike household surveys, the SAM includes the amounts (shares) of food groups consumed and does not allow for calculating discrete measures following a simulation where households already consume all foods. The DDS obtained by using the entropy index has already been widely used in the literature and provides a good estimate of dietary diversity (Theil & Finke, 1983; Wang et al., 2017). An increase in DDS has been found to be associated with higher socioeconomic status, greater household food security and improved nutritional outcomes (Hatløy et al., 1998, 2000; Tarini et al., 1999).

In addition to household consumption and dietary diversity, price changes resulting from changes in policy also have an impact on welfare levels. The effect on welfare was assessed using EV, which measures the changes in welfare associated with a price change. It is the change in income that results in a consumer moving to a new level of satisfaction associated with the consumption of a commodity. EV is interpreted as the amount of money that, if taken away from consumers without changing prices, would have the same effect on utility as a price change.

2.2 | Data sources

The model was calibrated using the Kenya SAM for 2018. The Kenya SAM 2018 had 55 production activities and 46 commodities, implying that one commodity may be produced by different activities and that one activity could produce more than one commodity (e.g., cattle production would produce meat and milk, while chicken production would produce chicken and eggs). The maize sector was disaggregated into 13 agroecological zones.

Income elasticities of demand for commodities at the household level were obtained from the estimations by the Joint Research Centre of the European Union (Vigani et al., 2019).

3 | RESULTS

3.1 | Production

The effects of a 20% increase in TFP of milk, chicken, eggs and beef are presented in Figure 1. In Sim 1, maize production would increase by 4.8%, milk by 5.2%, chicken by 4.9%, eggs by 4.9% and beef by 2.8%. The increase in maize production is explained by the fact that it is an intermediate input in both cattle and chicken production: when cattle and chicken production increase, the demand for maize for animal feed thus also increases.

In scenario 2 where the increase in TFP was coupled with a 25% reduction in transaction costs (trade and transportation margins), production would increase more for all the commodities: maize production increased by 11.8%, milk by 5.9%, chicken by 13.9%, eggs by 13.9% and beef meat by 4.2%. The significant increase in the production of maize can be explained, as previously mentioned, by the fact that it is a key input in cattle and chicken production. Overall, as transaction costs hinder the flow of goods, reducing the former in addition to increasing TFP would have a much larger impact compared with solely increasing TFP. For chicken and eggs, in particular, the change in production under Sim 2 was more than double that of Sim 1.

Simulation 3, which consisted of increasing TFP for both ASF and maize by 20%, would result in increased production of maize (by 8.1%), milk (by 6.8%), chicken (by 8.0%), eggs (by 8.0%) and beef (by 2.9%). Increasing TFP without addressing trade and transportation margins thus would result in a much smaller change in production.

3.2 | Consumer price changes

All the policy simulation scenarios would result in a reduction in the composite price (average of imported and domestic prices) for milk, chicken, eggs and beef due to the increased supply, as shown in Figure 2. For milk and meat, the largest decreases were observed in the third scenario, which included the reduction in the prices of maize. The chicken sector was more sensitive to the reduction in trade and transportation margins. As mentioned above, in the case of maize (Sim 1 and 2), increased production of chicken, milk, eggs and meat results in an increase in the demand for maize, which is an intermediate input for these sectors. With a limited supply of maize, the composite price of maize would increase. However, as expected, in scenario 3 the increase in TFP for maize products would result in a reduction in maize prices by 15.6%.

3.3 | Household consumption

Household expenditure shares, as a percentage of total food expenditure, on the four focus foods, are presented in Table 1. Generally, most households showed a higher expenditure share for milk compared with all other ASF, with beef accounting for the smallest share: the average household (both in rural and urban areas) spent less than 1% of its total food expenditure on beef.

The effects of the first simulation, a 20% increase in TFP for ASF on household consumption, are presented in Table 2 (Sim 1). Changes in consumption are driven by both income and price changes, as well as elasticities. In particular, when there is a decrease in domestic prices, a household's reaction depends on the price elasticity and the

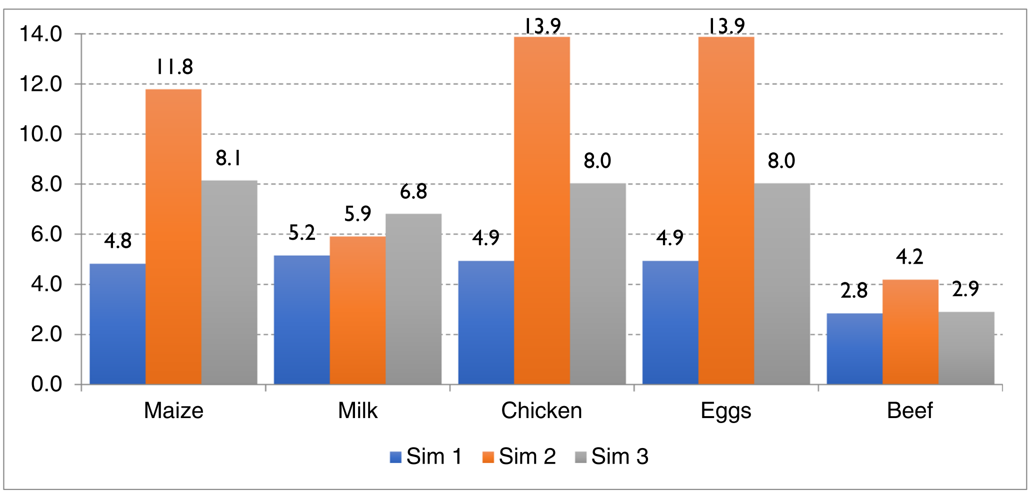

FIGURE 1 Effect of implementing policy changes on production (%). *Source*: Authors' computation.

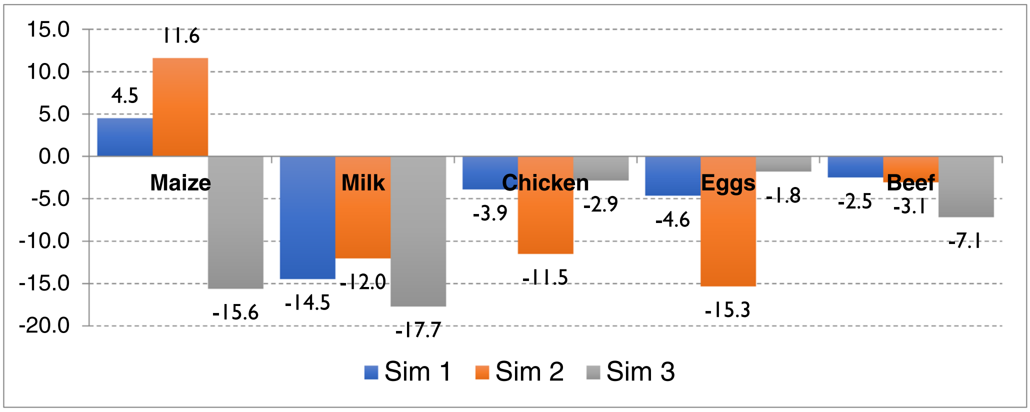

FIGURE 2 The effect of implementing policy changes for five foods of focus on consumer prices (%). *Source*: Authors' computation.

TABLE 1 Average household food expenditure shares as a percentage of total food expenditure (per capita).

Location	Quintile	Milk (%)	Chicken (%)	Eggs (%)	Beef (%)
Rural	Quintile 1 (poorest)	12.4	0.4	0.4	0.2
	Quintile 2	11.4	1.1	0.7	0.2
	Quintile 3	10.5	1.8	0.9	0.4
	Quintile 4	10.7	2.5	1.1	0.5
	Quintile 5 (richest)	9.1	2.7	1.3	0.9
Urban	Quintile 1 (poorest)	10.7	0.3	0.5	0.3
	Quintile 2	10.7	0.7	0.7	0.3
	Quintile 3	10.5	0.9	0.9	0.6
	Quintile 4	10.2	1.1	1.2	0.5
	Quintile 5 (richest)	9.1	2.1	1.4	0.9

Source: Authors' computation.

elasticity of substitution between the domestic variety and the imported one.

Improving diets through policy requires influencing household consumption patterns. Due to the larger decrease in milk prices compared with all other ASF, we observe the highest increases in milk consumption, followed by chicken and eggs. On average, all households increased their consumption of ASF under the simulations. For all ASF, increases are generally larger in rural than urban households, and the second-poorest urban quintile records the highest increase in consumption when ASF productivity is increased.

The results of implementing a 20% increase in TFP for ASF and a 25% reduction in trade margins and transportation costs (transaction costs) are presented in Table 2, Sim 2. The main objective when reducing transaction costs is to reduce the gap between producer and consumer prices. Producer prices are expected to increase, while those paid by the consumer will fall. For all ASF, rural households benefit the most from these policy changes. For instance, chicken consumption increases by 11%–13% for rural households, while in urban households the increase ranges from 8% to 11%. The increase in egg consumption for all households ranges from 8% to 16%. Milk and meat consumption also show some increases, but of a lesser magnitude than chicken and eggs. This is due to chicken and eggs having higher transportation costs and trade margins, resulting in high transaction costs; if infrastructure challenges faced by chicken and egg farmers were dealt with, household consumption of these products would significantly increase.

The results of Sim 3 are presented in Table 2. The objective of this simulation was to increase maize production to lower maize prices, which will be reflected in animal feed prices. As shown in Figure 2, maize prices decreased by almost 16% in this scenario, with effects on ASF prices; the prices of milk and meat would register the largest decreases. Increased maize productivity resulted in higher crop yields and outputs, leading to reduced animal feed prices, hence lower prices and increased consumption of ASF. The consumption of all focus commodities would increase for both urban and rural households, but the magnitudes of these increases would vary. In contrast to Sim 2, average consumption would increase more for milk and meat (compared with chicken and eggs), the prices of which are most impacted (Figure 2). The poorest 40% of the population (quintiles 1 and 2) in rural areas and quintile 2 in urban areas would register the largest increases in consumption.

3.4 | DDS

Increasing TFP and reducing transaction costs (Sims 1 and 2) would have the effect of increasing consumption of ASF, as presented in Table 3. The magnitude of the impact on consumption shares would vary across different households. In particular, rural households would record increases in DDS, with rural quintile 2 registering the largest increase. Urban households showed mixed changes: in general, there were positive changes in DDS, with quintiles 2 and 4 registering the largest increases (more than 1%). In Sim 2, there was a larger increase in DDS for all households.

TABLE 2 Effects of implementing a 20% increase in TFP for ASF on consumption per adult equivalent—% change.

Location	Quintiles	Milk (%)	Chicken (%)	Eggs (%)	Meat (%)
		Simulation 1			
Rural	Quintile 1 (poorest)	5.9	4.8	5.6	3.2
	Quintile 2	5.7	4.9	4.1	3.2
	Quintile 3	5.4	4.5	4.5	2.9
	Quintile 4	5.4	4.4	4.0	2.9
	Quintile 5 (richest)	5.1	3.8	3.1	2.4
Urban	Quintile 1 (poorest)	5.3	2.6	3.2	1.8
	Quintile 2	6.7	5.5	5.8	4.5
	Quintile 3	5.5	3.3	3.3	2.4
	Quintile 4	5.6	3.3	3.1	2.5
	Quintile 5 (richest)	5.6	3.0	2.5	2.1
		Simulation 2			
Rural	Quintile 1 (poorest)	6.6	12.6	16.3	5.6
	Quintile 2	6.8	13.1	12.4	6.1
	Quintile 3	6.6	13.1	14.5	6.0
	Quintile 4	6.5	12.6	12.7	5.8
	Quintile 5 (richest)	5.7	11.2	10.3	4.6
Urban	Quintile 1 (poorest)	5.2	8.4	11.6	3.4
	Quintile 2	6.6	11.3	13.7	6.0
	Quintile 3	5.5	9.2	10.7	4.1
	Quintile 4	6.0	9.8	10.2	4.8
	Quintile 5 (richest)	5.3	8.6	8.3	3.3
		Simulation 3			
Rural	Quintile 1 (poorest)	7.6	5.0	4.7	5.9
	Quintile 2	7.3	5.0	3.4	5.8
	Quintile 3	6.9	4.6	3.7	5.4
	Quintile 4	7.0	4.8	3.5	5.6
	Quintile 5 (richest)	6.9	4.5	2.9	5.3
Urban	Quintile 1 (poorest)	7.9	3.9	3.6	6.1
	Quintile 2	9.9	7.7	7.0	9.5
	Quintile 3	8.1	4.7	3.8	6.7
	Quintile 4	8.2	4.7	3.4	6.8
	Quintile 5 (richest)	8.5	4.7	3.0	6.8

Abbreviations: ASF, animal-source foods; TFP, total factor productivity.

In Simulation 3, there were positive changes in DDS for all households, with the second quintiles presenting the largest gains in both rural and urban areas. The largest DDS changes were achieved when policies aimed at both increasing ASF productivity and reducing transaction costs were put in place. However, the extent of increases in DDS was limited.

3.5 | EV

Supporting Information: Table A1 shows that both rural and urban households would register positive changes in welfare, measured using EV. For all four commodities, greater increases in welfare were recorded when increased TFP was accompanied by a reduction in trade margins and transportation costs (Sim 2) compared with increased TFP only (Sim 1): larger price reductions resulted in higher welfare gains. Increases in welfare obtained in the third simulation, which involved reducing animal feed prices through maize (Sim 3), were smaller than those of Sim 2, but still significant compared with Sim 1. Contrary to what one might expect, urban households (consumers) did not always experience the largest welfare gains resulting from the simulated policy changes.

4 | DISCUSSION

Through a series of simulations using a CGE model specifically calibrated to the Kenyan context, this analysis has sought to determine how certain policy changes would impact the availability and price of ASF and the downstream impact on welfare and consumption of these foods. The results suggest that increasing productivity for the four ASF studied (milk, chicken, eggs and beef) would increase their availability and lower consumer prices.

The change in productivity simulated here indicates what would happen if agricultural land, labour, capital and/or materials (agricultural inputs) were more efficiently used to produce a country's crops and livestock (agricultural outputs). In practice, increases in TFP in the livestock sector can result from numerous smaller changes: new technologies, including the introduction of new breeds; improved animal feed and care practices; increasing economies of scale; better managerial skills; and changes in the organization of production. These changes can be supported by more specifically directed policies and strategies, such as greater support for livestock breeding programmes. As another example, feed quality is a key determinant of livestock productivity, but high-quality animal feed is often hard to access in much of Africa; increasing access to it could help to increase the productivity of several ASF.

The impact of increased product supply on prices depends on many factors, including the trading status of the product (whether the country is a net importer or exporter, Kenya being a net importer), the demand elasticity, the presence of substitute goods and the level of transaction costs. For instance, limited price reductions are expected for products that are mainly exported if there is a high elasticity of transformation between domestic sales and exports and high demand elasticity. The opposite is true for products not exported or with low export shares, or low transformation elasticity and low demand elasticity. This can be seen in this study's results: all

TABLE 3 Percentage changes in DDS scores for households.

Location	Quintiles	Baseline value (%)	Sim 1 (% change)	Sim 2 (% change)	Sim 3 (% change)
Rural	Quintile 1 (Poorest)	1.1	1.7	2.7	1.9
	Quintile 2	0.9	1.9	3.4	2.1
	Quintile 3	1.0	1.6	3.4	1.8
	Quintile 4	0.9	1.7	3.6	1.8
	Quintile 5 (Richest)	0.9	1.5	3.2	1.6
Urban	Quintile 1 (Poorest)	1.2	0.7	1.4	0.6
	Quintile 2	0.5	2.5	4.2	2.9
	Quintile 3	0.9	0.9	2.2	0.9
	Quintile 4	0.7	1.1	2.9	1.1
	Quintile 5 (Richest)	0.7	1.0	2.5	0.0

Abbreviation: DDS, Dietary Diversity Score.

other factors being equal, we observed that milk prices fall significantly compared with prices for other ASF, because of the low demand elasticity of milk (Korir et al., 2018).

As a result of the simulated policy changes, we found that household consumption of the four foods would increase, depending on income level, the initial shares of the ASF considered and their demand elasticity. In turn, the increases in consumption would lead to (small) improvements in DDS, particularly for rural households, and further research will be needed to determine the resulting reduction in nutrient gaps. There would be larger welfare gains for poorer households than for richer households in both urban and rural areas, with the richest urban quintile experiencing no change in welfare.

When accompanied by a 25% reduction in trade margins and transportation costs, the positive results are amplified for all households, partly solving the 'food price dilemma' in which producers want higher margins, which could entail higher consumer prices—the opposite of what consumers want. This highlights the impact of insufficient investment in road and transportation infrastructure, which limits the ability to access markets because of the distance, time and high transportation costs. Previous studies have also explored the potential gains that would come from reducing transportation costs in Kenya. For example, Ramos et al. (2021) simulated the effects of a road infrastructure investment programme (4 billion Kenyan Shillings) and found that this would imply a 30% reduction in trade and transportation margins throughout Kenya, a reduction in ASF prices from 0.13% to 0.33% and an increase in consumption of up to 0.38%. Data from the Food and Agriculture Organization (FAO) suggest the annual savings in the cost of a least-cost nutrient-adequate diet arising from transportation cost reductions in Kenya could be as high as USD 7/person/year (FAO, 2020a, 2020b). This represents 3% of the food poverty line and with an average household size of four (KNBS, 2018), potential savings would amount to USD 28/household/year.

Increasing market competition and lowering the shares of profits claimed by intermediaries are also key elements in achieving lower trade margins. Food markets in Kenya are characterized by a high degree of market power for intermediaries, who can exert this power by paying below-competitive prices to farmers and charging above-competitive prices to consumers, accumulating more gains from reduced trading costs than either consumers or farmers (Bergquist, 2017).

Our study findings showed that increased maize productivity could reduce the price of maize, an intermediate input for ASF. This price decrease is transmitted to ASF prices, leading to increased consumption and improved welfare indicators. Increasing productivity in the maize sector could involve improved seed varieties, efficiency gains, economies of scale and changes in the organization of production. Improved access to and better use of inputs through targeted subsidies can also play a significant role. Initiatives such as 'Kilimo Plus', which sought to improve effectiveness and efficiency in agricultural production and proved successful in increasing maize productivity through better access to fertilizers and improved seeds, should be encouraged (Mason et al., 2017). Increasing maize production, however, should be accompanied by attempts to increase agrobiodiversity to improve both the environmental sustainability of production and the nutritional profile of the foods produced (Van Vliet et al., 2021). Furthermore, the cost structure of the ASF industry does include other inputs, including those that are imported. Reducing taxes and customs duties on these imported inputs is a policy that could be simulated for further analysis.

The policy changes simulated in this study have proven successful in several countries. In the 2022 state of food security and nutrition in the world, the extensive literature and country reviews performed on how agricultural policies affect diets, show that increasing productivity (through research and development and knowledge transfers) and investing in infrastructure to reduce transaction costs was key in the delivery of affordable healthy diets and environmental sustainability (FAO et al., 2022). The role of market structure (competition) has also been highlighted in providing lower prices for consumers (Covic & Hendriks, 2016; FAO, 2020a, 2020b).

There are several limitations to this analysis. First, a CGE model is an aggregate modelling tool and only provides broad results. It would be useful to complement this analysis with household data and microsimulation, which could give more detailed results. Second, the DDS measure we are using cannot handle the extensive margins of the modelling, so the results should be seen as lower bounds in terms of dietary impact. Due to the limitations of the model, we used a dietary diversity metric that is not commonly used in nutrition research, which can make the results more challenging for a nutrition audience to interpret or compare with other work. The modelling exercise did not include the cost of the policies, which is also a key consideration in implementation. It also did not consider the feasibility of implementing the policies, including the political-economic considerations that might be associated with doing so.

AUTHOR CONTRIBUTIONS

Fousseini Traoré and Miriam Omolo designed the model and performed the simulations. Fousseini Traoré, Miriam Omolo, Ty Beal, Stella Nordhagen, Patrick Codjia, Laura Kiige, Penjani Kamudoni, Caroline Arimi, Veronica Kirogo, Flaminia Ortenzi and Eric Djimeu Wouabe wrote the paper.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

Bergquist, L. F. (2017). *Pass-through, competition, and entry in agricultural markets: Experimental evidence from Kenya*. Working paper. University of Chicago.

Covic, N., & Hendriks, S. L. (2016). *Achieving a nutrition revolution for Africa: The road to healthier diets and optimal nutrition*. IFPRI. https://doi.org/10.2499/9780896295933

FAO, IFAD, UNICEF, WFP, & WHO. (2022). *The state of food security and nutrition in the world 2022. Repurposing food and agricultural policies to make healthy diets more affordable*. FAO. https://doi.org/10.4060/cc0639en

Food and Agriculture Organization (FAO). (2020a). *Cost and affordability of healthy diets across and within countries*. Background Paper for the State of Food Security and Nutrition in the World 2020. https://doi.org/10.4060/cb2431en

Food and Agriculture Organization (FAO). (2020b). *Fruit and vegetables—Your dietary essentials. The international year of fruits and vegetables*. Background paper, 2021. www.fao.org/documents/card/en/c/cb2395en

Global Alliance for Improved Nutrition (GAIN). (2016, November). *Marketplace for nutritious foods program a pilot case study evaluation of a nutritious food business in Kenya*.

Global Alliance for Improved Nutrition (GAIN), & United Nations Children's Fund (UNICEF). (2021). *Comprehensive Nutrient Gap Assessment (CONGA): Micronutrient gaps during the complementary feeding period*.

Hatløy, A., Hallund, J., Diarra, M. M., & Oshaug, A. (2000). Food variety, socioeconomic status and nutritional status in urban and rural areas in Koutiala (Mali). *Public Health Nutrition*, *3*, 57–65.

Hatløy, A., Torheim, L., & Oshaug, A. (1998). Food variety—A good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. *European Journal of Clinical Nutrition*, *52*, 891–898.

Headey, D. D., & Alderman, H. H. (2019). The relative caloric prices of healthy and unhealthy foods differ systematically across income levels and continents. *The Journal of Nutrition*, *149*(11), 2020–2033. https://doi.org/10.1093/jn/nxz158

Kennedy, G., Ballard, T., & Dop, M. C. (2011). *Guidelines for measuring household and individual dietary diversity*. FAO and European Union.

Kenya Medical Research Institute, Kenya National Bureau of Statistics, Kenya Ministry of Health, United Nations Children's Fund (UNICEF), Micronutrient Initiative, & Global Alliance for Improved Nutrition (GAIN). (2011). *The Kenya national micronutrient survey (KNMS)*.

Korir, L., Rizov, M., & Ruto, E. (2018). Analysis of household food demand and its implications on food security in Kenya: An application of QUAIDS model (92nd Annual Conference, April 16-18, 2018, Warwick University, Coventry, UK No. 273474). *Agricultural Economics Society*. https://econpapers.repec.org/paper/agsaesc18/273474.htm

KNBS. (2014). *Kenya demographic health survey report*.

KNBS. (2018). *Basic report on well-being in Kenya 2015/16*.

Lofgren, H., Lee, R., & Robinson, H. S. (2002). *A standard computable general equilibrium (CGE) model in GAMS*. The International Food Policy Research Institute (IFPRI).

Marivoet, W., Ulimwengu, J. M., & Sall, L. M. (2020). *Kenya policy atlas on food and nutrition security and resilience*.

Mason, N. M., Wineman, A., Kirimi, L., & Mather, D. (2017). *The effects of Kenya's 'smarter' input subsidy program on crop production, incomes and poverty*. Feed the Future Policy Research Brief 26. Michigan State University.

Murphy, S. P., & Allen, L. H. (2003, November). Nutritional importance of animal source foods. *The Journal of Nutrition*, *133*(11), 3932S–3935S.

Nordhagen, S., Beal, T., & Haddad, L. (2020). *The role of animal-source foods in healthy, sustainable, and equitable food systems*. Discussion paper series #5. Global Alliance for Improved Nutrition (GAIN). https://doi.org/10.36072/dp.5

Ramos, M. P., Custodio, E., Jiménez, S., Mainar-Causapé, A. J., Boulanger, P., & Ferrari, E. (2021). Do agri-food market incentives improve food security and nutrition indicators? A microsimulation evaluation for Kenya. *Food Security*, *14*, 209–227. https://doi.org/10.1007/s12571-021-01215-2

Rathnayake, K. M., Madushani, P., & Silva, K. (2012). Use of dietary diversity score as a proxy indicator of nutrient adequacy of rural elderly people in Sri Lanka. *BMC Research Notes*, *5*, 469. https://doi.org/10.1186/1756-0500-5-469

Ryckman, T., Beal, T., Codjia, P., Nordhagen, S., Arimi, C., Kirogo, V., Kiige, L., & Kamudoni, P. (2022). Affordability of nutritious foods for complementary feeding in Kenya: A subnational affordability assessment. *Maternal and Child Nutrition*, 1–17.

Tarini, A., Bakari, S., & Delisle, H. (1999). The overall nutritional quality of the diet is reflected in the growth of Nigerian children. *Sante*, *9*, 23–31.

Theil, H., & Finke, R. (1983). The consumer's demand for diversity. *European Economic Review*, *23*, 395–400.

United Nations Children's Fund (UNICEF). (2020). *Improving young children's diets during the complementary feeding period—UNICEF Programming Guidance* [Internet]. Retrieved August 2021 from: https://www.unicef.org/documents/improving-young-childrens-diets-during-complementary-feeding-period-unicef-programming

Vigani, M., Dudu, H., Ferrari, E., & Mainar, A. (2019, February). *Estimation of food demand parameters in Kenya*. JRC Technical Reports. https://doi.org/10.2760/479781

Van Vliet, S., Provenza, F. D., & Kronberg, S. L. (2021). Health-promoting phytonutrients are higher in grass-fed meat and milk. *Frontiers in Sustainable Food Systems*, *4*, 299.

Wang, H., Liu, C., Fan, H., & Tian, X. (2017). Rising food accessibility contributed to the increasing dietary diversity in rural and urban China. *Asia Pacific Journal of Clinical Nutrition*, *26*(4), 738–747.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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