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Assessing Food Security in Ethiopia with USDA ERS's New Food Security Modeling Approach

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Abstract

Purpose: We analyze several dimensions of food security in Ethiopia, taking into account projected population growth, economic growth, and price information to estimate future food consumption by income decile. The analysis looks at the potential impact of large consumer price increases on food security metrics.

Methodology: We use USDA ERS's new modeling framework for its annual International Food Security Assessment. The modeling approach captures economic behavior by making food demand systematically responsive to income and price changes—a demand specification wellgrounded in microeconomic foundations. The projected change in food consumption can be apportioned to population growth, income growth, and changes in food prices and real exchange rates.

Findings: Ethiopia is highly food-insecure, with 54% of the population (52 million people) consuming less than 2,100 calories a day in the base year (average 2013–15). Income growth under unchanged prices mitigates food insecurity with the number of food insecure people falling to 42.5 million in 2016. If domestic prices were free to fall with world market prices, the food insecure population would decrease further to 36.1 million. If domestic prices increased because of domestic supply shocks and constrained imports, the food-insecure population could rise to 64.7 million. The food gap (i.e., the amount of food necessary to eliminate food insecurity in the whole country) would reach 3.6 million tons.

Implications: The current policy of promoting food security through autarky has some severe limitations. Allowing private traders to import food grains and hedge price variations and exchange rate changes, would greatly improve food security in Ethiopia.

Keywords

food security, Ethiopia, food demand, food gap, price increase, food imports

Disciplines

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JEL codes: Q17, Q18

Introduction

The International Food Security Assessment (IFSA) model—used by USDA's Economic Research Service to project food gaps and the number of food-insecure people in 76 low- and middle-income countries—was re-specified to take advantage of food price data that have become available since the model was first developed in the mid-1990s. The new modeling approach captures economic behavior by making food demand systematically responsive to income and price changes (Beghin, Meade, and Rosen, forthcoming). One advantage of the new model specification is that it can be used to directly analyze the impacts of price shocks on food security in any given country included in the assessment. In this chapter, we focus on food security in Ethiopia. Our assessment using the modeling approach provides complementary insights to those based on more localized analysis of food security at the village and household level (see Beghin and Teshome in this volume).

Historically, Ethiopia was one of the most food-insecure countries in the world. A nearly two-decade-long civil war and collectivist regime, which ended in 1991, had many devastating impacts, among them a neglected agricultural sector. During the Derg regime, land was redistributed to smallholders and private enterprise was discouraged. Severe droughts exacerbated the impact of these policies and resulted in large famines with several hundred thousands deaths (de Waal, 1991). During the 1980s, grain output stagnated, meaning a secular decline on a per capita basis given population growth. Output rose through the 1990s as populations displaced by war were able to farm again. However, according to USDA's Economic Research Service, roughly 90% of the country's population remained food insecure into the early 2000s. Since that time, grain production has more than doubled due to government extension efforts and the provision of seeds, fertilizer, and credit to smallholders. In fact, depending on the year (due to impacts of weather variation), Ethiopia is now the first or second largest grain producer in Sub-Saharan Africa (competing for this position with Nigeria). Ethiopia produces about 95% of the grain it consumes and continues to restrict trade in staple food products. Therefore, in this policy environment, stable domestic production is key to stable supplies and prices given the tight governmental control on grain trade (USDA FAS, 2013, 2015). Erratic and insufficient rains in the current growing season due to El Niño are expected to have an adverse impact on output and increase food prices. When these production shortfalls happened in the past (2002–03 and 2006–07), real food prices (yearly average) rose more than 20%, and government interventions were not sufficient to smooth out the effects of these supply shocks. The new IFSA model is used in this chapter to analyze the impact of such significant price increases on food security in the current (2016) year compared to the 2013–15 average base used for the model calibration. To gauge these impacts, we use several key food security metrics (food insecure population, food gap per food-insecure person and in aggregate).

The food insecurity indicators are explained below. We use a nutritional target of 2,100 calories per capita per day, converted to grain equivalent, as a reference calorie intake to be food secure. The number of food insecure people can be measured as the number or percentage of the population who fail to meet the nutritional target, and are thus chronically food insecure. The food gap—the amount of food required to bring the food insecure population up to the nutritional target—provides a measure of the depth of food insecurity at both the individual (daily caloric shortfall) and aggregate level (1,000 MT annual national need).

Model Framework

Summary

The new modeling approach captures economic behavior by making food demand systematically responsive to income and price changes. The modeling approach is based on a simple price-independent generalized logarithmic (PIGLOG) demand system, a general specification well-grounded in microeconomic foundations (Muelbauer, 1975). More comprehensive discussions of the methodology applied here are available in Beghin, Meade, and Rosen (2015, forthcoming). Four food groups are modeled: major grain, all other grains, roots and tubers, and "all other foods." Grains and roots/tubers make up between 50%–80% of the diet in most low- and middle-income, food-insecure countries.

The new approach has several desirable characteristics. First, it allows for an aggregation of decile demands over 10 income deciles for each food category to an aggregate market demand that is consistent with a single agent's optimizing decisions. Second, the PIGLOG framework yields the average per capita aggregate demand, expressed as a function of average per capita income and the Theil (1967) index of income inequality, where average consumption decreases as inequality rises.

Finally, the approach accounts for two aspects of quality in food demand related to income. First, as incomes rise, consumers favor more expensive food groups and substitute away from staple foods to more expensive sources of nutrition like meat and vegetable oil, captured in "other foods." We account for this phenomenon by having a higher income elasticity for the non-staple food group. Similarly, price responses are stronger for more expensive food groups. Policies or market shocks that affect prices of any of the four groups and/or consumer income will generate changes in the composition of the food basket and consequently changes in levels of calorie consumption since the four groups have different caloric density.

The second dimension of food quality is more nuanced. The new approach allows for variable quality of food items within food groups, where quality of a given food item increases as income grows. Quality upgrade within any food group is well documented (Deaton 1988, 1990; Grunert 2005; and Reardon and Farina 2002, among others). This implies that consumers in lower income deciles purchase cheaper calories than do higher income consumers, and that price drops will lead to a stronger caloric response. Various qualities within a given food category are aggregated into an average-quality equivalent that leaves county-level data unchanged.

Using this framework, a country's projected change in food consumption can be apportioned to its main drivers: population growth, income growth, and changes in food prices and real exchange rates. The new approach allows closer examination of these key drivers of food security. For a more complete discussion see Beghin, Meade, and Rosen (forthcoming).

Demand system specification

This section borrows heavily from the model presentation of Beghin, Meade, and Rosen (2015, forthcoming). The PIGLOG demand system for Ethiopia considers four food categories: major grain (maize); an aggregate "other grains" consisting of teff, wheat, and sorghum; roots and tubers; and "all other" foods. The specification of the PIGLOG expenditure share of an individual consumer on food group i, w_i, is $w_i = A_i(p_i) + B_i(p_i)\ln(x)$, where x is the income of the consumer and p_i is the price of good i, both of which are expressed in real terms. Marshallian demand q_i is

$$q_i = (x/p_i)(A_i(p_i) + B_i(p_i)\ln(x)). \qquad (1)$$

We further simplify and linearize $A_i(p_i) = a_{i0} + a_{i1}p_i$, and $B_i(p_i) = b_{i0} + b_{i1}p_i$. This specification is parsimonious and focuses on the own-price response. All cross-price effects are subsumed in parameters a_{i0} and b_{i0}. These effects are hard to disaggregate as cross-price responses are most of the time not available.

The income elasticity of demand for food group *i* is

$$\varepsilon_{q_i x} = 1 + (b_{i0} + b_{i1} p_i)/w_i \,, \qquad (2)$$

which is decreasing in income if B_i is negative. Equation (2) accommodates normal or inferior goods and a range of elasticities over deciles as the share of expenditure w_i varies by decile. The own-price elasticity is

$$\varepsilon_{q_i p_i} = -1 + (p_i/w_i)(a_{i1} + b_{i1}\ln(x)). \qquad (3)$$

Equation (3) also accommodates a range of price elasticities by decile as income and share of expenditure vary by income decile. When calibrated appropriately, the absolute value of the own-price elasticity shown in (3) will be decreasing with income, which is intuitive.

The PIGLOG formulation leads to an aggregation of income decile-level demands for any good into the total market demand, or average per capita market demand, which is a function of average income corrected by Theil's entropy measure of income inequality, *z*, (Muelbauer, 1975) and which uses the same preference parameters as the demand of any individual consumer from any decile.

The specification of the demand for food group *i*, for income-decile *h*=1,…,10 is:

$$q_i^h = \left(\frac{x^h}{p_i}\right)(A_i(p_i) + B_i(p_i)\ln(x^h)) \qquad (4)$$

Equation (4) leads to average per capita demand $\overline{q}_i$ for good *i* by simple aggregation over deciles. The latter is a function of average per capita income $\bar{x}$ and Theil's entropy measure of income inequality *z* measured on the decile income distribution:

$$\overline{q_\imath} = \left(\frac{\bar{x}}{p_i}\right)(A_i(p_i) + B_i(p_i)\,(\ln(\bar{x}) + \ln(\frac{10}{z})) \qquad (5),$$

with $\ln(10/z) = \ln(10) + \sum_{h=1}^{10}(x^h/X)\ln(x^h/X)$, and with aggregate income $X = \sum_{h=1}^{10} 10\bar{x}$.

Entropy measure z reaches its maximum at 10 when all deciles have the same income. In this case ln(10/z) equals zero. Any income inequality leads to (10/z) > 1. Given some inequality and a negative value for $B_i(p_i)$, it can be seen that income inequality decreases the level of average consumption per capita for the corresponding good category. As shown in (5), abstracting from income inequality will overstate average demand relative to the average demand implied by the individual decile demands that account for unequal income distribution.

With the linearization of $A_i(p)$ and $B_i(p)$ as defined previously, average demand for good i is

$$\overline{q_i} = (\bar{x}/p_i)((a_{i0} + a_{i1}p_i) + (b_{i0} + b_{i1}p_i)(\ln(\bar{x}) + \ln(\tfrac{10}{z})). \quad (6)$$

The average expenditure share for good category i is

$$\overline{w_i} = (a_{i0} + a_{i1}p_i) + (b_{i0} + b_{i1}p_i)(\ln(\bar{x}) + \ln(\tfrac{10}{z}). \quad (7)$$

The elasticity of average demand for good i,, with respect to average income (or total expenditure), follows (2) but using average expenditure shares:

$$\varepsilon_{\bar{q}_i\bar{x}} = 1 + (b_{i0} + b_{i1})/\overline{w_i}\,. \quad (8)$$

Similarly, the own-price elasticity of the average demand follows (3), but uses the corrected average income inclusive of the correction for income inequality:

$$\varepsilon_{\bar{q}_i p_i} = -1 + (p_i/\overline{w_i})(a_{i1} + b_{i1}(\ln(\bar{x}) + \ln(\tfrac{10}{z})). \quad (9)$$

All consumers in different deciles have similar underlying preferences over any given good i as embodied in parameters a_{i0}, a_{i1}, b_{i0}, b_{i1}, and their respective consumptions vary because their respective incomes vary.

Model calibration

The calibration approach follows Beghin, Meade and Rosen (forthcoming) and we refer interested readers to their paper. We explain the data sources used for the Ethiopian calibration.

Table 1 summarizes the data used in calibrating demand for each of the four food groups. The model is calibrated based on average prices and income from 2013–2015. Prices are expressed in real birr per grain-equivalent kg of each food group *i*. We make conversions from nominal to real currency using exchange rates and CPIs from the USDA Macro Baseline. The average per capita income $\bar{x}$ is generated from USDA Macro Baseline population and GDP data and is also expressed in real birr. Data on income distribution by quintile from the World Bank's World Development Indicators are further disaggregated into deciles and are used to calculate the Theil index and to generate decile-level incomes.

<Insert Table 1 here>

The own-price and income elasticities used here are based on econometric estimates of Muhammad et al. (2011). This latter study comprises eight food groups, including grains, fruits and vegetables, meat and dairy products, and fats and oil. We use an average of all the elasticities except grains to estimate the price response of our "other food" group. We use .75* the grain elasticities to represent the 'roots and tubers' group.

FAO Food Balance Sheets (FBS) provide average annual consumption of each food group; grains are disaggregated allowing us to model major grain and other grains separately. When available, we use an annual average of domestic food prices from FAO's Global Information and Early Warning System (GIEWS). In Ethiopia, we observe domestic prices for the four most important food grains: maize (the "major grain" in this model), wheat, sorghum, and teff. For consistency with other country models in the global IFSA, we use the prices from the market in Addis Ababa, the capital city of Ethiopia. The price for the “other grains” food group is an average of the prices of all the other grains in the Ethiopian food basket (which appear in the FAO Food Balance Sheet), weighted by their calorie shares in the diet. The “other grains” food group for Ethiopia includes wheat, sorghum, teff (other cereals in the FBS), barley, millet, and oats. We do not observe the domestic price for the latter three—their consumption levels are relatively small and their prices tend to follow price patterns of the major grains.

For the food prices that we do not observe (“other food,” “roots and tubers,” and the minor grains), we create a synthetic domestic price, $p_i^{dom,syn}$ that is linked to the world price p_i^{world}; both are expressed in real birr. The world prices are from the USDA Baseline; we use cassava to represent the world root and tuber price, and soy oil to represent all other foods. The parameter θ is the price transmission slope, which we assume is .7. The parameter trc_{int} represents international transportation and market costs (e.g., CIF/FOB), which we assume are 10%, and trc_{dom} are domestic trade costs, which we assume are $20 USD per ton in real terms.

$$p_i^{dom,syn} = \theta^* p_i^{world} * \left(1 + \frac{trc_{int}}{\theta}\right) * \left(1 + \frac{tariff}{\theta}\right) + trc_{dom}. \qquad (10)$$

At this point, we also calibrate a price transmission equation that links the domestic price (either observed or synthetic) to the world price; we use this equation to translate world price projections into domestic prices during the projection period of the model (here just for 2016). The generic price transmission equation is $p_i^{dom} = \theta^* p_i^{world} + \widehat{intercept}$.

During the calibration stage, we solve for the intercept, in real birr per kg based on the domestic and world prices observed in the calibration period (2013–2015). We hold the intercept constant in real terms during the projection period (i.e., we assume the relationship between the world and domestic price does not change over time). For the policy scenarios, we are interested in changes in domestic prices, which could be seen as coming from changes in world markets as expressed in equation (10), or alternatively if borders are closed, from displacement in the domestic equilibrium with restricted trade or no trade. In the latter case then, the link to the world market does not hold, but a local equilibrium condition implicitly equates demand and supply locally. Any shock in the domestic supply would then have strong local price effects. This explanation rationalizes looking at domestic price shocks unrelated to world price shocks.

Quality scaling

Consistent with real-world observation, we assume that the quality of good *i* increases with income and that its price is also increasing with quality. Therefore, low-income consumers consume cheaper calories than high-income consumers. This quality is represented by a scaling factor $\mu(x)$ which, when normalized appropriately over all deciles, is equal to 1. The scaling factor scales quality and prices such that the product of quality-adjusted quantity consumed and prices (or the expenditure share) remains constant. The detailed procedure is explained in Beghin, Meade, and Rosen (2015).

The relevant element here for our Ethiopia case study is the definition of the consumption of the lowest income decile. To establish a reference consumption level for the bottom income decile for Ethiopia we estimate a lognormal distribution of calorie availability using the coefficient of variation in food consumption from FAO and IFAD’s State of Food Insecurity 2015 (SOFI) and the mean per capita consumption from the FAO Food Balance Sheet (235.5 kg/year or 2,130 kcal/day). The average food availability for the lowest income decile is 134.7 kg/year in grain equivalent, or 1,219 kcal per day (see Beghin, Meade, and Rosen, 2015 for the derivation).

Food security indicators

We generate two types of food security indicators for Ethiopia: the number of food-insecure people, and the food gap, using a nutritional target of target of 2,100 calories per person per day, which is 232.1 kg per capita per year in grain equivalent. We express the number of food-insecure as both a headcount as well as a percentage of the population. At the individual level, we express the food gap as the average amount of additional calories each food-insecure person would need to reach 2,100 calorie per day. We also express the food gap in terms of total volume of food in grain equivalent required to make everyone in the country food secure over the course of a year. We follow Beghin, Meade, and Rosen (2015) to compute these measures. Other indicators are possible (see for example, Antle, Adhikari, and Price, 2015).

Food Price Shocks and their Impacts

The 2015 El Niño led to a drought of historic proportions in many parts of Ethiopia and has affected Ethiopian grain production, resulting in lower than expected harvest in 2016 and causing food prices to spike (FEWSNET 2016; USDA-FAS 2016). In this section, we explore the potential impacts of higher 2016 food prices on chronic food security in Ethiopia for 2016. To gain insight into how a severe drought may affect food prices we look to 2008, when a drought occurred at the same time as world food prices soared, representing a worst-case scenario in terms of price impacts (GIEWS price data begin in 2000). Figure 1 shows domestic prices in Addis Ababa for the four most important food grains in Ethiopia. The monthly prices show large spikes in 2008, but they do not persist for the entire year. The annual average price for 2008 is, however, significantly above the pre-2008 average for all four grains. As of February 2016, food prices in Ethiopia have begun to climb as a result of the production shortfalls; typically the seasonal price increases begin much later in the year (Fewsnet 2016). The difference between the

2008 and pre-2008 annual average prices differ across the four grains. Maize was 64.3% higher, while the other crops (weighted by share in the food basket) were 42% higher.

<Figure I here>

We estimate food security indicators for 2016 under three price scenarios. Scenario I holds prices at calibration level (2013–2015 average), but allows income to rise to its projected level in 2016. Scenario II uses the worst-case scenario with price shocks, where maize (major grain) price is 64% higher than at model calibration (2013–2015 average) and other grain price is 42% higher than its calibration level. Because we do not observe domestic prices for the two other food groups, we assume their prices are 42% higher as well. The 2015 drought has already had adverse effects on pastoral conditions (Fewsnet, 2016), thus we would expect to see impacts on prices for food derived from livestock (an important component of our "other food" group). Scenario III projects domestic price based on world price transmission, as USDA ERS would typically implement in its price and food security projections; this is a "business as usual scenario." The 2016 prices for each scenario are shown in Table 2.

<Table 2 here>

The food security indicators for 2016 generated under the three hypothetical scenarios are shown in Table 3, along with the indicators for the base year (2013–2015 average). In the base year, Ethiopia is highly food-insecure, with 54% of the population (52 million people) consuming on average less than 2,100 calories a day. Under scenario I, if food prices remained at 2013–2015 real levels, the food security indicators for 2016 would improve noticeably, with the number of food insecure people falling to 42.5 million. This is because per capita incomes are expected to rise 14% in real terms from calibration levels in 2016. By construction, income in all deciles increases including the poorest ones, boosting food demand and reducing food insecurity.

The second scenario, the worst-case scenario, leads to a considerable increase in food insecurity in 2016 (see Table 3). The percentage of food insecure people rises to 63%, or 64.7 million. The distribution gap under this scenario is quite large at 3.598 million tons.

<Table 3 here>

The third scenario based on world price transmission shows much lower domestic prices since world prices are projected to fall in 2016 compared to the calibration level (2013–15 average). Consequently, even more significant improvements in food security indicators take place compared to the first scenario, with the population of food insecure falling to 36.1 million. This drop also corresponds to a fall in the distribution gap for 2016 at both the aggregate (1.504 million metric tons), and individual level (377 Kcal/day). This result is driven not only by rising incomes, as in scenario I, but also by the projected fall in world food prices for all commodities. An important policy implication follows: if Ethiopia opens its borders to trade, local food price increases can be dampened, thus benefiting consumers, but also affecting net sellers of the food crops negatively. The latter are presumably larger producers and therefore less vulnerable to face food insecurity. The natural hedge between price and output risk is constrained by lower prices if borders are open. Large transaction costs beyond Addis Ababa provide some natural protection to net producers in regions affected by drought.

Conclusions

In this chapter, we applied the newly developed model of USDA ERS for its annual international food security assessment to analyze food price shocks in Ethiopia and assess their impact on several measures of food security. The simulated shocks illustrate recent (and likely future shocks) experienced by food insecure households in Ethiopia.

The advantages of the new IFSA model are that it provides several key metrics and deeper insights on food security using a consumer demand estimation approach based on sound micro-economic foundations that allows us to evaluate responses to income and price shocks. Yet the model relies on existing public information on aggregate food consumption, income distribution, GDP measures, and a limited number of reference prices. These data requirements are low, and model calibration is possible with readily available economic information.

We found that income growth is a powerful driver of food security in Ethiopia. Nevertheless, the reliance on domestic production to stabilize production and consumer prices has major drawbacks. Inevitable supply shock can lead to significant price shocks, which can induce a deterioration of food security largely because the government of Ethiopia does not use food trade effectively to dampen these price shocks. The food security gains achieved with income growth can be entirely offset by price shocks that are likely to occur in the future.

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Table 1: Data used in the calibration of the Ethiopian food demand system

Food Group	Price (birr/Kg)	Consumption (Kg/year)	Income elasticity	Own price elasticity
Major Grain (maize)	2.71	42.08	0.62	-0.46
Other Grains	2.94	108.38	0.62	-0.46
Roots and Tubers	2.39	31.06	0.51	-0.38
Other Food	1.10	53.95	1	-0.73

Table 2: 2016 food prices per grain-equivalent Kg in different scenarios

	Scenario I: 2013-2015 price levels	Scenario II: worst case scenario	Scenario III: World price transmission scenario
Major Grain (maize)	2.71	4.44	2.59
Other Grains	2.94	4.18	2.85
Roots and Tubers	2.39	3.39	1.98
Other Food	1.10	1.57	.93

Table 3: Food security indicators for 2016 under different price scenarios

Food security measure	Base (2013-2015 average) for calibration	Scenario I: 2013-2015 price levels	Scenario II: worst case scenario	Scenario III: World price transmission scenario
Population Food Insecure				
Percentage	54%	41%	63%	35%
Count (millions of people)	52.1	42.5	64.7	36.1
Distribution Gap				
Individual Daily Gap (Kcal)	456	402	503	377
Annual Food Gap (1,000 mt)	2,629	1,890	3,598	1,504

Figure 1: Real retail cereal prices in Addis Ababa, Ethiopia (From FAO-GIEWS).