United States Department of Agriculture

Economic Research Service

Technical Bulletin Number 1941

June 2015

A Consistent Food Demand Framework for International Food Security Assessment

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Economic Research Service
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Recommended citation format for this publication:

Beghin, John, Birgit Meade, and Stacey Rosen. *A Consistent Food Demand Framework for International Food Security Assessment*, TB-1941, U.S. Department of Agriculture, Economic Research Service, June 2015.

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Abstract

A parsimonious demand modeling approach has been developed for the annual USDA-ERS *International Food Security Assessment* to be fully implemented in 2016. The approach incorporates price effects, variation in food quality across income deciles, and consistent aggregation over income deciles and food qualities. The approach is based on a simple PIGLOG demand approach for four food categories: corn, other grains, roots and tubers, and "all other" foods. The framework exhibits desirable characteristics obtained via calibration: food "quality" within a food group increases with income (e.g., from simple wheat flour purchased by poor households to commercial baked goods purchased by higher income groups); price and income responses become less sensitive with increasing income; and increasing income inequality decreases average per capita food consumption. The proposed modeling approach is illustrated for Tanzania. The new calibrated model will be able to identify the unique impacts of income, prices, and exchange rates on food consumption, i.e. potential sources of food insecurity.

Keywords: international food security, PIGLOG demand, aggregation, income inequality, food prices, shocks

Acknowledgments

We thank the four participants in the peer review process for this report: Titus Awokuse, University of Delaware; Marc Bellemare, University of Minnesota; Hui Jiang, USDA, Foreign Agricultural Service; and one anonymous reviewer. Thanks to Cheryl Christensen, Andrew Muhammad, and Gopinath Munisamy of USDA, Economic Research Service; participants at the 2014 International Agricultural Trade Research Consortium annual meetings in San Diego, CA, for discussions and comments; and Xiaoxiao Xie and Yiran Xu for research assistance. Beghin acknowledges support from USDA-ERS with Cooperative Agreement "Food Security Model Development," Agreement # 58-3000-3-0050, and from the Marlin Cole Chair at Iowa State University.

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On November 13, 2015, in section "Calibration for Good *i*," the equation under step 2, found at the bottom of page 6, was corrected by dividing $\bar{w}_i$ by p_i.

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A report summary from the Economic Research Service

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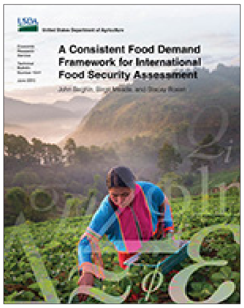

Find the full report at *www.ers.usda.gov/publications/tb-technical-bulletin/tb1941*

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What Is the Issue?

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—will be improved to take advantage of food price data that have become available since the model was first specified in the mid-1990s. In doing so, the model will be placed on firm microeconomic foundations. Furthermore, after dividing the population into 10 groups based on income, the calculation of food demand per decile will be changed to allow aggregation to a market demand that is consistent with average consumption data. Also, food quality is allowed to vary depending on the income level of consumers. The new demand framework will be the basis of ERS International Food Security Assessments starting in 2016. A prototype has been developed for Tanzania, which serves here to illustrate the new model features.

What Are the New Model Features?

The new modeling approach captures economic behavior by making food demand systematically responsive to income and price changes. The difference in food quantity consumed between a country's lowest and highest income groups is diminished by introducing the "quality" scaling factor that allows lower income consumers to purchase lower value food items within a food group at a lower price compared with higher income consumers. By setting the average scaling factor to 1, aggregated demand across income deciles remains unchanged. Finally, 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 will allow a closer examination of key drivers of food insecurity.

The modeling framework has several new features:

- Demand can be aggregated across income deciles to arrive at a consistent measure of average market demand;
- Food quality is modeled to increase with income;
- Price and income responses become less sensitive as income increases; and
- Greater income inequality reduces average per capita food consumption.

ERS is a primary source of economic research and analysis from the U.S. Department of Agriculture, providing timely information on economic and policy issues related to agriculture, food, the environment, and rural America.

How Does the New Model Work?

The improved modeling approach is based on a simple price-independent generalized logarithmic (PIGLOG) demand approach for four food categories (major grain, other grains, roots and tubers, and “all other” foods), a general specification well-grounded in microeconomic foundations. Grains and roots/tubers make up between 50 and 80 percent of the diet in most low- and middle-income, food-insecure countries. The new approach allows for an explicit aggregation of demand over 10 income deciles for each food category to an aggregate market demand and relies on data currently available for the International Food Security Assessment model, complemented by own-price and income elasticities, and additionally available price data.

The new approach is illustrated for Tanzania, which was chosen because the country is part of the U.S. Federal Government’s Feed the Future program and because consumption data are robust due to several recent household surveys.

A Consistent Food Demand Framework for International Food Security Assessment

Introduction

This report proposes a systematic approach to introducing prices, food quality differences, and consistent aggregation across income decile consumption into the economic model that is currently used by USDA's Economic Research Service in its annual *International Food Security Assessment* (IFSA). The IFSA projects food consumption per decile for 76 low- and middle-income countries over the next 10 years. This report derives a food demand system for four categories of food—major grain, other grains, roots and tubers, and "all other" foods—to be used in the 2016 food security assessment. A prototype has been developed for Tanzania, which serves here to illustrate the new model features.

The approach is based on the widely used price-independent generalized logarithmic (PIGLOG) demand approach. The report explains how to consistently aggregate food demand across income deciles into average consumption per capita as a function of average income and a correction factor accounting for income distribution across population deciles. Many demand characterizations—including the approach in the current ERS model—describe an average aggregate behavior as if all consumers were identical, whereas behavior tends to vary, with different income and price responses across deciles. The proposed new approach incorporates a measure of income distribution by decile and provides an aggregate market-average demand for each food category, which is a function of average income corrected for income inequality across deciles.

This approach accounts for two aspects of *quality* in food availability as it relates to income. First, as income increases, consumers demand more expensive calories and favor more expensive food groups. We account for that by having a higher income elasticity for nonstaple food items than for staple food groups. Within staples, we have a greater income response for grains than for roots and tubers.[1] Similarly, price responses are stronger for more expensive food groups like meat and dairy. Policy changes, which may affect food prices and/or consumer income, will alter the composition of the food basket, leading to caloric changes since the four food groups have different caloric densities.

Second, the PIGLOG approach allows for variable quality of food items within food groups, with quality increasing as income grows. "Quality" here refers to higher value food products within a food group. We follow Deaton (1988) and express unit value (price adjusted for quality) as price multiplied, or "scaled," by quality. We call this our quality scaling factor. Income-driven quality upgrades within food groups have been documented by Deaton (1988) and (1990), Grunert (2005), Reardon and Farina (2002), Van Rijswijk and Frewer (2008), and Yu and Abler (2009). Various qualities within a given food category are aggregated into an average-quality equivalent that leaves country-level data unchanged. Wealthier consumers purchase higher value goods relative to poorer consumers. Consumers in different income deciles face different prices in accordance with quality.

[1]Grains and roots/tubers make up more than half and up to 80 percent of the diet in most low- and middle-income, food-insecure countries.

Consumers in lower income deciles purchase cheaper calories than do higher income consumers, and price drops will lead to a stronger caloric response. Within each food category, demand for items of varying quality can be aggregated across income deciles to arrive at "average quality-equivalent" units. Domestic and world prices are linked through synthetic transmission equations, which include tariffs, real exchange rates, transportation, and other trade costs.

This report further explains how to calibrate food demand using the limited data typically available for the annual IFSA, namely average per capita consumption, income projections and distribution, domestic and international prices, and estimates of income and own-price elasticities (Muhammad et al., 2011).

This report focuses on Tanzania and its staple grain, corn. Excel files (available from the authors) present data behind the price transmission equations and demand system and for the four food categories, with projections for 2013-2023. The model presented here uses information on estimated food consumption from the Tanzania model in the 2013 *International Food Security Assessment* (USDA-ERS, 2013).

Specification of Consumer Demand

The PIGLOG specification (Muellbauer, 1975; Lewbel, 1989) is a general specification, well grounded in micro-economic foundations and widely used in food demand analysis. It allows for an explicit aggregation of demand by the 10 income deciles for each food category into an aggregate market demand. It provides "exact" aggregation such that aggregate market behavior is consistent with a single agent's optimizing decisions as determined by prices and average income. The PIGLOG framework[2] also yields the average per capita aggregate demand, expressed as a function of average per capita income and the Theil (1967) index of income inequality.[3] Finally, the PIGLOG specification exhibits shares of food expenditure that decrease with real income given the appropriate calibration. Expenditure shares per food category can be summed and demands per category aggregated into calories or grain-calorie equivalents. We initially assume that quality is constant, but then use the scaling approach to capture variable quality and prices within food categories and across income deciles.

Because of the lack of data on cross-price elasticities for many countries, cross-price effects are left out of our specification. This is a drawback, especially when a single commodity price varies while others remain unchanged. The PIGLOG framework is best suited to examine price surges affecting most food groups, in which case substitution effects are limited.

The specification of the PIGLOG expenditure share on food category i, w_i, is

$$w_i = A_i(p_i / P) + B_i(p_i / P)\ln(x / P), \qquad (1)$$

with variable x being the nominal income of the consumer, and with nominal price p_i and price index P for all other goods, which can be approximated by the CPI. Functions A and B are homogenous of degree zero in nominal prices p_i and P. We normalize P to 1 without any loss of generality and rewrite the share as $w_i = A_i(p_i) + B_i(p_i)\ln(x)$, with price and income variables in real terms from here on. The expenditure share decreases with income, with B being negative. Marshallian demand q_i is

$$q_i(p_i, P, x) = (x / p_i)\left(A_i(p_i) + B_i(p_i)\ln(x)\right). \qquad (2)$$

We further specify $A_i(p_i)=a_{io} + a_{i1}\, p_i$, and $B_i(p_i)=b_{io}+b_{i1}\, p_i$. While other specifications are possible, equation (2) is parsimonious and focuses on the own-price response. All other cross-price effects are subsumed in parameters a_{io} and b_{io}. When data and cross-price estimates become available, more elaborate responses can include cross-price effects in future refinements and extensions.

The income elasticity of demand i is

$$\varepsilon_{q_i x} = 1 + (B_i(p_i) / w_i) = 1 + [(b_{io} + b_{i1} p_i) / w_i], \qquad (3)$$

which decreases with income. If B_i is negative, equation (3) accommodates normal or inferior goods and a range of elasticities over income deciles as the share of expenditure w_i varies by decile.

[2]The main alternative to PIGLOG models is the Rotterdam model, which would not easily allow for exact aggregation of demand across income deciles.

[3]We do not account for income derived from wealth, which could affect labor participation decisions and labor income. A low-income person could have significant wealth.

The own-price elasticity is

$$\varepsilon_{q_i p_i} = -1 + (p_i / w_i)(b_{i1} \ln(x) + a_{i1}). \quad (4)$$

Equation (4) also accommodates a range of elasticities by decile as income and share of expenditure vary. When calibrated appropriately, income elasticity (3) and expenditure share (1) decrease with income. Similarly, the absolute value of price elasticity (4) can be calibrated to decrease with income.

Aggregating Decile Demands

The PIGLOG formulation allows for aggregation of decile-level demands for any good into 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 (Muellbauer, 1975) and which uses the same preference parameters as the demand of any one decile.

Using superscript h to denote decile-specific variables with h=1,…,10, we have decile-level food demand as

$$q_i^h = (x^h / p_i)\left(A_i(p_i) + B_i(p_i)\ln(x^h)\right) \tag{5}$$

Equation (5) leads to average per capita demand $\overline{q}_i$ by simple aggregation over deciles. The latter is a function of average per capita income $\overline{x}$ and Theil's entropy measure of income inequality z measured on the decile income distribution (Muellbauer, 1975):

$$\overline{q}_i = (\overline{x} / p_i)\left(A_i(p_i) + B_i(p_i)(\ln(\overline{x}) + \ln(10/z))\right), \tag{6}$$

with

$$\ln(10/z) = \ln(10) + \sum_{h=1}^{10}(x^h / X)\ln(x^h / X), \text{ and with } X = \sum_{h=1}^{10} x^h = 10\overline{x}. \tag{7}$$

Entropy measure z reaches its maximum at 10 when all deciles have similar 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 $B_i(p_i)$, income inequality reduces the level of average consumption per capita for the corresponding food category. As shown in (6), abstracting from income inequality will overstate average demand relative to the average demand implied by the individual decile demands.

With our chosen specifications of $A_i(p)$ and $B_i(p)$ as defined previously, we can further express average demand for good i as

$$\overline{q}_i = (\overline{x} / p_i)\left((a_{io} + a_{i1}p_i) + (b_{io} + b_{i1}p_i)(\ln(\overline{x}) + \ln(10/z))\right). \tag{8}$$

We also define average expenditure share for good category i as

$$\overline{w}_i = \left((a_{io} + a_{i1}p_i) + [(b_{io} + b_{i1}p_i)(\ln(\overline{x}) + \ln(10/z))]\right). \tag{9}$$

The elasticity of average demand for good i with respect to average income (or total expenditure) can have any sign and is

$$\varepsilon_{\overline{q}_i\overline{x}} = 1 + (B_i(p_i)/\overline{w}_i) = 1 + [(b_{io} + b_{i1}p_i)/\overline{w}_i]. \tag{10}$$

The (negative) own-price elasticity of the average demand is

$$\varepsilon_{\overline{q}_i p_i} = -1 + (p_i/\overline{w}_i)(b_{i1}(\ln(\overline{x}) + \ln(10/z)) + a_{i1}). \tag{11}$$

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

Calibration for Good i

Data on average consumption and income are available from the Food Security database maintained by USDA-ERS, which relies substantially on food availability data from the Food and Agriculture Organization of the United Nations (FAO). From income distribution data (World Development Indicators), one can compute the Theil index (equation 7). Using equations (9) through (11) for the average expenditure share and the two elasticities of average demand for good i, demand $\overline{q}_i$ can be calibrated. Then, individual decile demands q_i^h can be calibrated using the parameters recovered in the calibration of average demand. The calibration uses the observed average expenditure shares of good i, an estimate of the two elasticities for average demand, and a specified value of a free parameter as explained below.

With a system of three linear equations (equations 9-11) with four unknown variables, one parameter remains free. The free parameter (chosen to be b_{io}) is used to ensure that demands by income decile behave in accordance with stylized facts of food demand. For example, price sensitivity and income responsiveness decline with income levels, own-price elasticities are negative, and food expenditure shares tend to fall with increasing income. A range of values for the free parameters helps to ensure that these stylized facts are satisfied by the calibrated demand system. Here, we illustrate this by pinning down b_{io} such that the ratio of price elasticities for the bottom and top deciles falls proportionally with the ratio of the natural logarithm of their income ($\ln(x_1)/\ln(x_{10})$) in the base year. That ratio in Tanzania's case is 2.932.

For any given free parameter value, the system of equations is solved for parameters b_{i1}, a_{i1}, and a_{io} as a function of the free parameter. Once these three parameters are recovered, the decile demands and their corresponding elasticities are computed based on the decile income levels and the aggregate elasticities. This step relies on the four parameters (one free parameter and three calibrated) and equation (2) with $A_i(p_i)=a_{io} + a_{i1} p_i$, and $B_i(p_i)=b_{io}+b_{i1} p_i$ for the demands and (3) and (4) for each decile elasticity.

The calibration is recursive. Four steps are involved:

1. Parameter b_{i1} is first recovered from the income elasticity estimate $\hat{\varepsilon}_{\overline{q}_i\overline{x}}$ and for a given value of $\hat{b}_{io}$, both denoted by hats, that is,

   $$\hat{\varepsilon}_{\overline{q}_i\overline{x}} = 1 + (B_i(p_i)/\overline{w}_i) = 1 + [(\hat{b}_{io} + b_{i1}p_i)/\overline{w}_i],$$

   leading to

   $$\tilde{b}_{i1} = [\overline{w}_i(\hat{\varepsilon}_{\overline{q}_i\overline{x}} - 1) - \hat{b}_{io}]/p_i.$$

(Tildes denote calibrated values.)

2. Next, the calibrated value of the a_{i1} parameter is recovered, given calibrated parameter $\tilde{b}_{i1}$, an estimate of the own-price elasticity of the aggregate average demand for good i $\hat{\varepsilon}_{\overline{q}_i p_i}$, and the observed average income and Theil index z. The expression for the calibrated value of parameter a_{i1} is

   $$\tilde{a}_{i1} = (\overline{w}_i/p_i)(\hat{\varepsilon}_{\overline{q}_i p_i} + 1) - \tilde{b}_{i1}(\ln(\overline{x}) + \ln(10/z))$$

3. The calibrated value of the last parameter a_{io} is recovered from the average expenditure share (9),

$$\tilde{a}_{io} = \overline{w}_i - \left(\tilde{a}_{i1} p_i + (\hat{b}_{io} + \tilde{b}_{i1} p_i)(\ln(\overline{x}) + \ln(10/z))\right).$$

4. Parameters $\tilde{a}_{io}, \tilde{a}_{i1}, \hat{b}_{io}$, and $\tilde{b}_{i1}$, along with income x^h and price p_i, are used to generate the consumption level of good *i* for each income decile. Similarly, one can compute the associated decile-specific elasticities of demand with respect to income and price using equations (2)-(4). Again, in this initial calibration, the quality of good *i* is assumed constant across deciles. We choose $\hat{b}_{io}$ to set the ratio of price elasticities for the bottom and top deciles equal to the ratio of the natural logarithm of their national income shares in the base year; we use the solver in Excel to pin down b_0 such that $(\varepsilon^1_{\bar{q}_i p_i} / \varepsilon^{10}_{\bar{q}_i p_i}) = (\ln(x^1/10\overline{x}) / \ln(x^{10}/10\overline{x}))$.

   Alternatively, there is a range of values for b_o that satisfy the calibration. The range is price and income dependent and satisfies $b_0 < -b_1 p$ for the expenditure share to fall with increasing income, and $b_1 < 0$ and $b_1 \ln(x) + a_1 < w$ for the pric`e elasticity to fall with increasing income. We use the ratio of top and bottom deciles' elasticities and income shares in order to have a transparent rule that is consistently applied to all four food groups and many countries, and to ensure that over the range of observed income and aggregate income shares, the demand system exhibits the desired stylized patterns.

Step 4 completes the calibration and characterization of each income decile's consumption of any given good *i,* assuming that quality remains the same across all deciles. The four-step process illustrates the link between decile demand and aggregate market demand. It also demonstrates the correspondence between income and price responsiveness of the average and individual per capita demands through aggregation over individual decile demands. In the context of the food security outlook, the same sequence of steps is undertaken for the four food categories in Tanzania (see appendix). The four categories are common to all potential countries included in the IFSA, but the major staple grain will be country-specific and the composition of "other grains," roots/tubers, and "all other foods" will also be country-specific.

Price Index for Aggregate Category

Three of the food categories (other grains, roots/tubers, and aggregate food) include several commodities. For goods with international and/or domestic price data available (i.e., grains), we use a weighted (by share of consumption) price index aggregating prices of various grains into a composite grain price index. For other products (roots/tubers and all other foods), this approach is flawed as nutritional content per unit of weight varies dramatically across goods (e.g., dairy, meat, oils, vegetables), so aggregation is on a grain-based equivalence.

For roots/tubers, the international price of cassava is used as a representative world price because it is the only consistently available root and tuber price and it is linked to local prices of roots/tubers such as yam or manioc from FAO's Global Information and Early Warning System (GIEWS) when available for 2012. All prices are in grain equivalent. The price of vegetable oil in grain equivalent is used as a representative price for "all other food." "All other food" consists mostly of higher value products such as vegetable oil, which is a universally consumed food item with a readily available international and—in some instances—local price. Using the price for "vegetable oil" as a proxy for "all other food" is not ideal, but defensible. Other representative commodities could be used.

Synthetic price transmission equations are used to link the world and domestic prices, expressed in grain equivalent. The transmission equation includes tariffs and transportation costs from world markets to the domestic market, as well as the effect of the real exchange rate, assuming imperfect transmission between world and domestic prices.

Aggregation Over the Four Food Categories

We aggregate the four food types to derive a caloric or grain equivalent to the estimated demands. The four food categories are expressed in calorie-equivalents in FAO's data and can be easily converted to grain-equivalent. Each food category is characterized by a grain or calorie energy intake per unit of consumption (1 gram of corn has about 3.5 calories). Naturally, the four categories of demand can be aggregated to a total grain or calorie equivalent, which in turn responds to price and income via the economics underlying each of the four food types. Tables 1a and 1b show the calibration for corn per income decile in Tanzania and table 2 shows the elasticities for each food category by decile.

Table 1a
Data and calculated parameters used to calibrate the Tanzania PIGLOG corn demand, 2012 base year

Data	Value	Unit
Average income	444,171	real LCU/capita
Average corn quantity consumed	74.6	kg/capita
Aggregate income elasticity	0.56	unitless
Aggregate price elasticity	-0.413	unitless
Consumer price, corn	286	real LCU/kg
Average corn expenditure share	0.048	unitless
Theil index (ln(10/z)) computed from decile data	0.229	unitless
bo free parameter (set freely)	-0.01648207	
b1 (computed)	-0.00001583	
a1 (computed)	0.00030801	
ao (computed)	0.23796806	

* The Theil index is a measure of income inequality. The entropy measure z reaches its maximum at 10 when all deciles have similar income. In this case, ln(10/*z*) equals zero. Any income inequality leads to (10/*z*) > 1.
**The a and b parameters are part of demand equation (2). a1 and b1 and are used to express own-price responses; b0 and b1 are used to express income elasticity.
LCU = local currency unit.

Table 1b

Demand calibration and quality adjustment per income decile: corn demand in Tanzania

Decile	Income shares by decile	Computed decile expenditure share	Computed decile income elasticities	Computed decile price elasticities	Quality scale	Implied daily calories from corn	Daily calories adjusted for quality	Calibrated decile average demands	Annual consumption corrected for quality
	Percent					Calories per capita/year		Kg per capita/year	
1	2.8	8	0.74	-0.49	0.61	312	511	35	57
2	4.0	7	0.71	-0.48	0.73	400	550	45	61
3	5.1	7	0.69	-0.47	0.82	477	584	53	65
4	6.0	6	0.67	-0.46	0.87	531	608	59	68
5	7.0	6	0.65	-0.45	0.93	588	633	66	71
6	8.6	6	0.63	-0.44	1	669	669	75	75
7	9.6	5	0.61	-0.44	1.04	716	690	80	77
8	12.2	5	0.57	-0.42	1.12	825	739	92	82
9	15.2	4	0.52	-0.39	1.19	933	786	104	88
10	29.6	3	0.3	-0.29	1.34	1,240	922	138	103

Table 2

Food demand elasticities by income decile calculated from calibration

	Grains (2 categories)		Roots/tubers		Other food	
	Elasticities					
Income decile	Income	Price	Income	Price	Income	Price
1	0.74	-0.56	0.72	-0.41	0.86	-0.95
2	0.71	-0.54	0.69	-0.39	0.86	-0.88
3	0.69	-0.52	0.66	-0.38	0.85	-0.83
4	0.67	-0.50	0.64	-0.37	0.85	-0.80
5	0.65	-0.49	0.62	-0.36	0.85	-0.76
6	0.63	-0.47	0.59	-0.35	0.84	-0.71
7	0.61	-0.45	0.57	-0.34	0.84	-0.68
8	0.57	-0.42	0.52	-0.31	0.83	-0.62
9	0.52	-0.38	0.46	-0.29	0.82	-0.55
10	0.30	-0.19	0.15	-0.14	0.80	-0.32
Average, aggregated	0.56	-0.41	0.51	-0.31	0.83	-0.61

Price Transmission

Following Mundlak and Larson (1992), Campa and Goldberg (2005), and others, the price transmission equation links the local consumer price of good *i* to the corresponding world market price and embodies the influence of world prices, international transportation, exchange rates, trade policy, and other marketing costs. Each real consumer price for any tradable importable commodity *i* is linked to the corresponding world market price as follows:

$$p_i = (\theta ER\ (wp_i(1+trc_{\text{int}}/\theta)(1+tariff/\theta)) + trc_{\text{dom}})/P, \tag{12}$$

where θ is the slope indicating the strength of transmission between the world price and the domestic price, *ER* is the nominal exchange rate in local currency units per U.S. dollar, wp_i is the FOB (free on board) price of commodity *i*, *trc* denotes trade and transportation costs in the international market (*int* subscript) in ad valorem form and in the domestic market of the importing country in specific form (*dom* subscript), *tariff* denotes the sum of all specific and ad valorem tariffs imposed on the good and expressed in ad valorem form, and *P* is the CPI deflator (or GDP deflator)

Table 3a
Price transmission in Tanzania, by food group

Food category	Priced item	Exportable	Importable	Observed	Synthetic	Domestic price in real TSh in grain equivalent	International price in real TSh in grain equivalent	International price location from USDA outlook	Implied intercept (DP-WP)
Major grain (corn)	Corn		X	X		286,404	224,806	USDA	61,598
All other grains	Rice		X	X		938,911	465,782	Thailand, USDA	473,128
	Wheat		X		X	355,066	236,093	U.S. hard red winter, USDA	118,972
	Sorghum		X		X	281,787	214,926	U.S. sorghum, USDA	66,861
	Millet	X			X	230,742	214,926	U.S. sorghum, USDA	15,816
	Barley		X		X	308,988	213,216	Rouen barley, USDA	95,772
	Grain index		X		X	592,736	331,954	Computed	260,781
Roots/tubers	Cassava		X		X	1,663,415	1,198,254	International cassava, USDA	465,161
Other food	Soy oil		X		X	448,442	357,542	Soy oil, USDA	90,900

Note: TSh = Tanzanian shilling.
Source: USDA, Economic Research Service

in the importing country as defined previously following equation 1. Trade and transportation costs can be commodity-specific. In a world of perfect transmission, θ is equal to 1. The impacts of the tariff and international transportation costs are passed on fully and held constant after the initial calibration, reducing the elasticity of the domestic price with respect to the international price.

Equation (12) can be recast with world price *wp* expressed as a real world price *rwp* (real constant US dollars/metric ton), real exchange rate *RER* (real local currency units (LCU) per real U.S. dollar), and real trade costs *rtrc* other than tariffs and international transportation cost in real LCUs, and then not further deflating by the local CPI deflator *P*. This step yields:

$$p_i = (\theta RER\ (rwp_i(1+trc_{\text{int}}/\theta)(1+tariff/\theta)) + rtrc_{\text{dom}}) \qquad (12')$$

Other specifications than (12) or (12') are possible, especially if econometric estimates of price transmissions are available. An intercept can be added, or a slope coefficient to (12) to reflect the econometric estimates of a regression of the type (p = a + b wp). The additive form of (12) and (12') provides a price-transmission elasticity (dln$p$/dlnrwp), which is less than 1 as long as additive tariff or trade costs can be lowered by setting the slope parameter θ to a value smaller than 1. For example, in the Tanzania illustration, we assume a slope θ of 0.7. The magnitude of transmission coefficients is uncertain, with a wide range (0.002-0.99) observed by Amikuzuno and Kolawole (2013) and Minot (2011). We chose a slope of 0.7 in light of Minot's finding that staple food prices in Sub-Saharan Africa rose by about three-quarters of the increase in world prices in 2007-08.

The price transmission equation allows for two sets of circumstances: (*a*) both domestic and international prices are available, and an intercept (which subsumes all trade costs between world and domestic markets) can be derived to link the two prices expressed in similar real local currency units (LCUs); or (*b*) only the international price is available and a synthetic domestic price is estimated using the price transmission described in (12). To compute (12), tariffs are obtained from WTO (WITS and/or Macmap databases are alternatives); the CPI deflator *P* is available from the USDA-ERS macro database; FOB/Cost, Insurance, and Freight (CIF) ratios are estimated at 1.10 in *ad valorem* form for importable goods. (FOB/CIF ratios are disregarded for exportable goods, as are tariffs since the price signal is in the export market.) Domestic trade costs are assumed to be $20 per metric ton of grain equivalent (2005 real prices), consistent with the range of domestic transportation costs in Africa as reported in Badiane et al. (2014). World price data are obtained from USDA's (10-year) Agricultural Projections.

Table 3b
Price transmission in Tanzania, supporting data

	Percent
Real exchange rate	929.7
CPI U.S.	117.56
CPI Tanzania	197.07
CIF/FOB	10
Tariff: Wheat (percent)	31
Tariff: Sorghum (percent)	13
Tariff: Millet (percent)	25
Tariff: Barley (percent)	25
Tariff: Corn (percent)	33
Tariff: Rice (percent)	29
Tariff: Soy oil (percent)	10
Tariff: Cassava (percent)	25
Slope of transmission θ	0.7

Notes: CPI = Consumer Price Index; CIF = Cost, insurance, freight; FOB = free on board
Source: USDA, Economic Research Service, and World Bank WITS data (World Integrated Trade Solutions)

Quality Scaling

Consistent with real-world observations, it is assumed that the quality of good *i* increases with income and that its price increases with quality. In other words, higher income consumers choose higher value products within a food group at higher prices than do lower income households. This behavior is represented by a scaling factor $\mu(x)$ which, when normalized appropriately over all income deciles, is equal to 1. We follow Deaton (1988) and express our quality scaling factor as price multiplied, or "scaled," by quality. Applying the scaling factor results in opposite movements of quality/price versus quantity in such a way that the estimated expenditure share is the same as without quality scaling.[4]

Using equation (2) and a definition of the scaling factor μ, we have a quantity consumed with variable quality for any good *i* and income decile *h*:

$$q^h_{i\,adj} = q^h_i / \mu^h_i = (x^h / \mu^h_i p_i)\left(A_i(p_i) + B_i(p_i)\ln(x^h)\right), \qquad (13)$$

with

$$\mu^h_i > 0\ \forall h, \text{ and } \sum_{h=1}^{10}(q^h_i / \mu^h_i)/10 = \overline{q}_i. \qquad (14)$$

Low-income deciles consume goods of cheaper quality in greater abundance ($q^h_{iadj} \geq q^h_i$ with μ^h smaller than 1) and higher income consumers consume higher quality goods in smaller amounts once expressed in quality-adjusted units ($q^h_{iadj} \leq q^h_i$ with μ^h larger than 1).

The scaling is calibrated such that, on average over deciles, the mean of the variable-quality consumption levels is equal to the mean per capita consumption, holding quality constant as expressed by equation (14). Expenditures are invariant to scaling since the price and quantity are inversely scaled and offset each other. One can think of consumption in average-quality equivalents (equation 2) or in variable-quality units (equation 13). To compute calorie availability, equation (13) is used.

To calibrate the demand system, we use equation (2) and then impose the scaling on top of the original demand calibration. To do so, a reference consumption level is established in variable-quality units for the first (lowest) decile, which is represented by $q^1_{iadj\,\min}$ in equation (15) below. This level for the first decile is based on additional sources of information from household surveys or other sources when these are available. It represents a credible level of consumption in grain equivalent for the poorest segment of the country. For Tanzania, we estimate a lognormal distribution (available from the authors) of calorie availability using FAO's data on food insecurity.

[4]The quality-scaling approach can also be rationalized using the framework of Cox and Wohlgenant (1986) of hedonic prices in which households in different deciles choose quality as part of their utility maximization problem. We do not attempt to model this hedonic choice explicitly here, however.

The scaling parameter μ for good i and decile h is derived using the adjusted consumption level as follows:

$$q^h_{iadj\,\min} = (\alpha + \beta q^h_i), \text{ or}$$

$$\mu^h_i = q^h_i / (\alpha + \beta q^h_i), \tag{15}$$

with

$$\beta = (\overline{q}_i - q^1_{iadj\,\min}) / (\overline{q}_i - q^1_i) \text{ and } \alpha = q^1_{iadj\,\min} - \beta q^1_i.$$

For the Tanzanian model, we use both the first (lowest) decile per capita availability implied by FAO's *State of Food Insecurity* in 2014 and updated data on food availability, which is 138.1 kg of grain equivalent per capita per year. Each of the four food groups contributes proportionally to the first decile's reference consumption level and each is scaled up to sum to the aggregate reference consumption level. The constraint of having the mean quality equal to 1 across all deciles provides a second equation to establish how quality evolves over deciles in any given year. The demand-weighted-average scaling factor is equal to 1, such that the scaling does not "create" consumption in the aggregation across income deciles. The sum of all consumption across deciles with variable quality sums to the same food volume estimated assuming constant average quality.

Over time, this minimum consumption in adjusted units is allowed to grow slowly, following the projected distribution of food availability in a country. In Tanzania, increases in quality within food groups are included by scaling up consumption in the four food categories to achieve a minimum aggregate calorie intake of 1,239 calories per day for the lowest income decile in the base year, then deriving a proportional minimum consumption and scaling schedule for each of the four categories so that aggregation is consistent. The quality scaling factor for corn is shown per decile in table 1 (see column labelled "quality scale") for 2012 in Tanzania.

The quality scaling structure evolves as income changes, moving across income deciles in any given year, here 2012 (fig. 1). Over time, the lowest decile's consumption grows with income.

We allow quality to increase (the scaling factor slowly increases, but remains below 1 for the lowest income groups), which translates into a net increase in consumption for those in the lowest income decile (fig. 2). Conversely, for deciles starting with above-average quality (scaling factor larger than 1 in the base year), quality adjustments diminish as income rises. Consequently, the range in quality of food narrows when everyone's income rises. This feature is a consequence of specifying that demand-weighted average quality be equal to 1 in all years.

There is some intuition to this feature—quality dispersion decreases when everyone's income rises. Figure 2 illustrates this change in scaling for the first decile in the Tanzanian model over the range of projected future income to 2023 and for the average quality adjustment.

One drawback of the approach is that it does not account for *average market quality* increasing over time. As countries become more affluent, quality likely improves for most food items. Hence, the scaling proposed here is relative rather than absolute since average quality remains equal to 1 over time.

Figure 1
Quality scaling by food type across income deciles, 2012

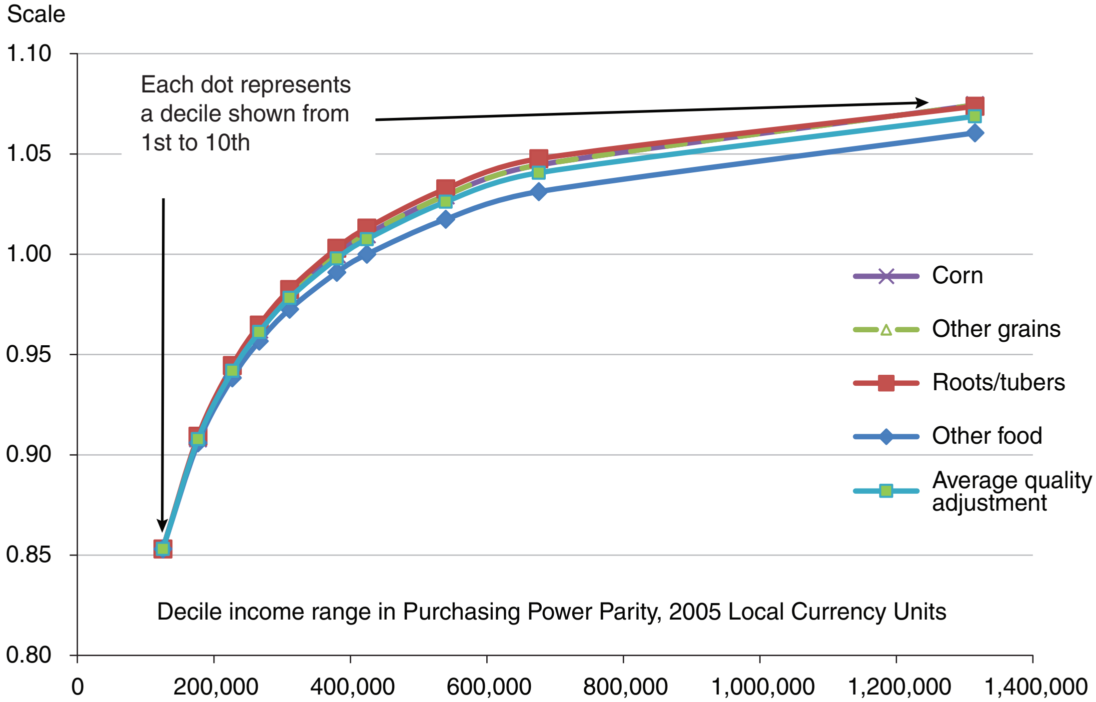
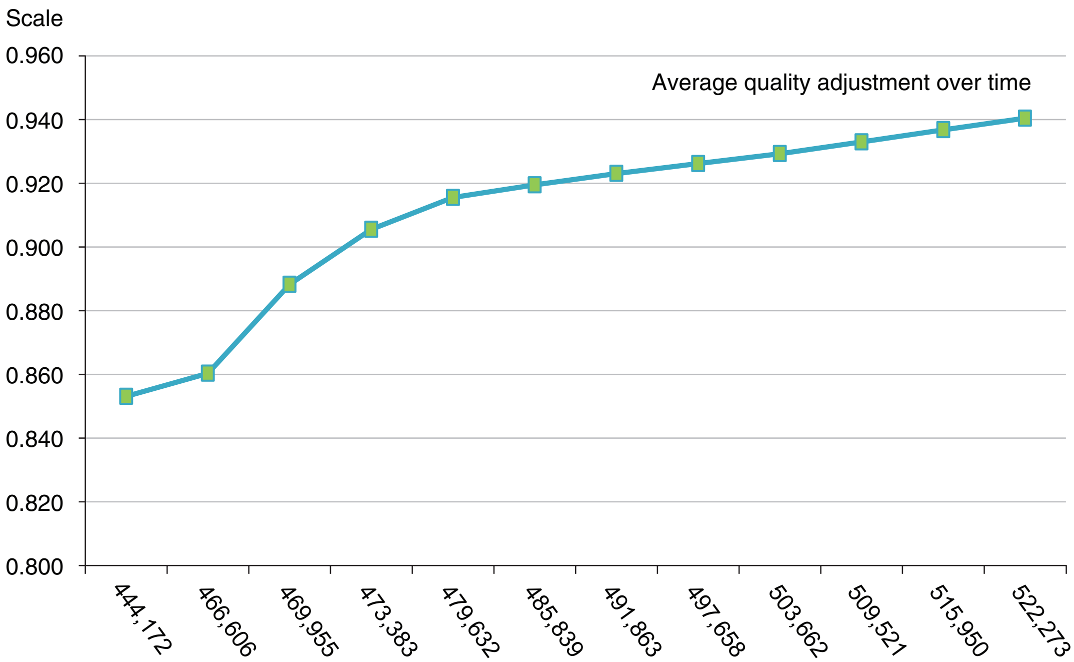


Figure 2
Quality adjustment of 1st decile with average income rising over time to 2023



Average income per capita, 2012-2023, in Tanzanian shillings.

Integrating the New Demand Approach into IFSA

This section explains how the new demand system will be integrated into the current model used for the *International Food Security Assessment*.

Projection of Food Supply

The simulation framework used for projecting aggregate food supply in IFSA is based on partial equilibrium recursive models of the low- and middle-income countries included. The country models are synthetic, meaning that the parameters used are either cross-country estimates or are estimated by other studies. Each country model includes historical production and use data on the two most important food categories: aggregate grains and roots/tubers. The two grain categories used on the demand side are aggregated back into a single grain category to match domestic supply and demand and determine imports residually. This disaggregation/re-aggregation of grains allows for better tracing of potential price shocks to that country's major grain, which could affect food security, while keeping the supply side of the model relatively tractable for a large number of countries.

In modeling, the "other foods" category represents all other consumed food products in order to capture the full diets of a country's inhabitants. "Other food" information is obtained from FAOSTAT food balance sheets by subtracting grain and root/tuber consumption from each country's consumption of total calories. This calorie measure can then be expressed in grain equivalent, using each country's conversion rate based on its consumption of particular grain products. All food commodities are converted into grain equivalent based on calorie content to allow aggregation.[5]

Production of grains and roots/tubers are each projected for a 10-year period, based on the most recent 3-year average of data on production, area, yield, and inputs. Projections are determined by the following area and yield response functions:

$$PR_{cnt} = AR_{cnt} * YL_{cnt}, \tag{16a}$$

$$YL_{cnt} = f\,(LB_{cnt}, FR_{cnt}, K_{cnt}, T_{cnt}), \tag{16b}$$

$$RPY_{cnt} = YL_{cnt} * DP_{cnt}, \tag{16c}$$

$$RNPY_{cnt} = NYL_{cnt} * NDP_{cnt}, \tag{16d}$$

$$AR_{cnt} = f\,(AR_{cnt-1}, RPY_{cnt-1}, RNPY_{cnt-1}, Z_{cnt}), \tag{16e}$$

where *PR* is production, *AR* is area, *YL* is yield, *LB* is rural labor, *FR* is fertilizer use, *K* is an indicator of capital use, *T* is the indicator of technology change, *DP* is real domestic price, *RPY* is the real gross return per acre, *NDP* is real domestic substitute price, *NYL* is yield of substitute commodity, *RNPY* is the real gross return per acre for the substitute commodity, and *Z* represents exogenous policies. The equations are calculated for all countries *c* and two commodities *n* (grains and roots/tubers). In other words, yield is a function of inputs such as rural labor and fertilizer, and area used for grains or roots/tubers is a function of lagged area as well as lagged return to grains and

[5]For example, grain has roughly 3.5 calories per gram and tubers have about 1 calorie per gram. One metric ton (MT) of tubers is therefore equivalent to 0.29 MT of grain (1 divided by 3.5), and 1 MT of vegetable oil (8 calories per gram) is equivalent to 2.29 tons of grain (8 divided by 3.5).

returns to roots/tubers. Policy indicators, if available, can also be included to better project the area planted.

The functional form chosen is a double-log equation. Crop area is a function of 1-year lagged (t-1) real gross returns to crop production, lagged returns (1-year lag) to substitute crops, and lagged crop area. Yield responds to input use: labor, fertilizer, capital, and technology change.

To close the model, we have a market equilibrium condition where imports are equal to the excess demand for the four commodities. In other words, imports (*Im*) are equal to demand (*q*) minus domestic supply (*S*):

$$Im_{cnt} = q_{cnt} - S_{cnt} \tag{17}$$

To close each domestic market, excess demand clears on the world market. The world and domestic price levels are linked through the transmission equations defined earlier. Net trade is the residual that satisfies the difference between domestic production and food demand. For many of the IFSA countries, production of grains and roots/tubers falls short of demand, leading to food imports. Countries are assumed to be price takers in the international market, meaning that world prices are exogenous in the model.

Data for the Supply Side

Historical crop production, supply/use, and trade data up to the most recent available year (2012 or 2013 when available) are from FAOSTAT, FAO/GIEWS, and USDA as of March 2014. Food aid data are from the UN's World Food Program (WFP) up to 2012. Population data are from the UN Population Division, 2012 Revision, medium variant. The base year data used for projections are the average for 2010-2012. A series of variables are assumed exogenous and projected outside the model, including population, world prices, agricultural inventories, seed use (constant base seed/area ratio), fertilizer, capital, and agricultural labor.

Food Security Indicators of the International Food Security Model

Two food insecurity indicators are estimated for the current year as well as 10 years out: the number of food-insecure people and the distribution gap (the gap between projected domestic food demand and the consumption target). Food security is defined in terms of four dimensions: food availability, food access, food utilization, and stability. No one analysis or indicator can address all four dimensions as they rely on very different types of information and data.

The main focus and contribution of the IFSA model, however, is its projection of food demand by income group. This focus on individual income groups allows for the analysis of access, or whether households have sufficient purchasing power to buy the food they need. For this purpose, we use the decile food demands, subject to income constraints and price responses, for the 10 income groups. Food demand by income decile is then compared with a nutritional target to determine whether a given income group is food secure.

The nutritional target is based on a daily caloric intake standard of about 2,100 calories per capita per day. The caloric target is converted into grain-equivalent quantities. This conversion is based on the calorie-per-gram relationship of grains and roots/tubers, weighted by each country's consumption shares. The consumption share of “other” food products is converted into grain equivalent based on the grain conversion rate.

If the estimated food demand falls below the target, the entire income decile is counted as food insecure. Totaling the people in these food-deficit income groups provides **the number of food-insecure people**. This indicator became a flagship measure in 1996 when 185 countries at the World Food Summit in Rome determined to reduce the number of food-insecure people by half by 2015. The decile approach has some shortcomings. For example, a whole income decile may be declared food secure, even though individual members of that decile could be food insecure. An alternative approach uses a full distribution of food availability[6] to derive an estimate of the projected prevalence of food insecurity.

Also, the number of food-insecure people provides no indication of the *depth* of food insecurity. A given income group might be consuming just below the target level, allowing for improvements in food security by slightly increasing access to food, either by income transfers or price policy. Another income group might be found to consume at half the target level, indicating severe food insecurity.

To illustrate the depth of food insecurity, we also evaluate IFSA countries based on the gap between projected domestic food demand and the consumption target. We call this gap the **distribution gap**. The objective is to allow each income group to reach the nutritional target. If food demand based on incomes and prices in a given income group is lower than this target, that difference is part of the distribution gap for this country. The gaps for all income groups are added up to determine the distribution gap for a given country. The distribution gap can be expressed as the total amount of food required to allow each income decile to reach the nutritional target, or as a ratio (percent of the target).

The results were formally validated by comparing caloric intake predicted by the new demand approach with predictions made by FAO in the State of Food Insecurity (SOFI) 2014 report, as implied by their distribution parameters.[7]

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[6]Distribution parameters used are provided by FAO.

[7]A log normal distribution was derived using the first two moments based on SOFI data. The consumption level implied by SOFI was used to correct the caloric intake of the bottom decile to make sure the new approach did not underestimate the caloric intake. The quality adjustment described in the model section eliminates the potential for underestimation. Furthermore, in subsequent work, the food security gap is derived using both the decile approach and the log normal distribution. The former (approach) assumes that either the entire decile is food insecure if its average consumption falls below the threshold level of food security, or that the entire decile is food secure if average consumption within the decile exceeds the threshold level, by whatever narrow margin, whereas the true food insecurity level might be somewhere in between. Results were compared between the two approaches and for two different caloric reference levels (1,800 and 2,100 calories). Those results are reported in the working paper version of this report at www.econ.iastate.edu/research/working-papers/p18196. The model was not extensively validated for the top decile because these deciles are not at risk of food insecurity.

Decomposition of Projected Demand

Total demand growth is decomposed into per capita demand growth and population growth. Then, per capita demand growth is decomposed in terms of income response and price response, which itself is decomposed into a real world price response and a real exchange rate response. The growth of projected total demand is then linearized as in Dong (2006), Heien and Wessells (1988), and Shui et al. (1993). The decomposition for infinitesimal changes is:

$$d\ln(totQ_i(pop, rwp, RER, \bar{x})) = d\ln(pop) + d\ln(\bar{q}_i)) = d\ln(pop) + \varepsilon_{\bar{q}_i p_i}\varepsilon_{p_i rwp_i}(d\ln(rwp) + d\ln(RER)) + \varepsilon_{\bar{q}_i \bar{x}} d\ln(\bar{x}),$$

discretely approximated by

$$\frac{\Delta totQ_i}{totQ_i} \approx (\frac{\Delta pop}{pop}+1)(1+\varepsilon_{\bar{q}_i p_i}\varepsilon_{p_i rwp_i}(\frac{\Delta rwp}{rwp}+\frac{\Delta RER}{RER}+\frac{\Delta rwp}{rwp}\frac{\Delta RER}{RER})+\varepsilon_{\bar{q}_i \bar{x}}\frac{\Delta \bar{x}}{\bar{x}})-1, \quad (18)$$

with $totQ_i$ denoting total food demand for commodity *i*, *pop* denoting population of the country, and $\varepsilon_{p_i rwp_i}$ being the price transmission elasticity. The growth rates *(Δx/x))* are taken from 2012 to 2023. The second equation in (18) is an approximation since the elasticities are endogenous and vary with price, quantities, and income.

The price transmission elasticity for corn in Tanzania is 0.785, evaluated for the price change at the border and then at the domestic consumer level, between 2012 and 2023. We compute the effects as follows. For the domestic price effect on per capita demand, we look at

$$\left(\frac{\bar{q}\left(p_{2023}, \bar{x}_{2012}\right)}{\bar{q}\left(p_{2012}, \bar{x}_{2012}\right)} - 1\right)$$

with real domestic price *p(rwp, RER*) defined as in equation (12'). This effect is then allocated proportionally to the relative changes in the *RER* and *rwp* between 2012 and 2023. For the income effect on per capita demand, we look at

$$\left(\frac{\bar{q}\left(p_{2012}, \bar{x}_{2023}\right)}{\bar{q}\left(p_{2012}, \bar{x}_{2012}\right)} - 1\right).$$

The sum of the two effects (domestic price and income) are then summed to approximate the relative change in per capita demand induced by the price, exchange rate, and income changes.

Based on the calibrated demands, total food demand for corn in Tanzania is projected to increase by 76 percent from 2012 to 2023 (table 4). Population growth is estimated at 35 percent over this period. Per capita demand is projected to grow by 30 percent based on the calibrated demand per capita (equation 8), given the trajectory of projected real income per capita (+18 percent), real world price for corn (-49 percent), and real exchange rate (-22 percent). Changes in population growth and per capita demand amplify each other, and this interaction is responsible for 11 percent of the growth in total demand.

Again, these figures are obtained using the calibrated demand and for the population average. A similar decomposition by decile would show more pronounced responses to changes in price, exchange rate, and income in low-income deciles relative to high-income deciles. These demand

Table 4

Decomposition of projected corn demand in Tanzania in terms of population growth, income per capita, world price, and real exchange rate, 2012-13

Variable	Demand	2012-2023 Projected rate of change	Aproximated effect on demand	Explanation
		Percent		
Real PPP income	Per cap	17.6	9.3	Income shift of per capita demand using arc elasticity of income, all else constant
Real world price (real US $)	Per cap	-48.7	14.0	Price response of per capita demand to world price change using approximate price elasticity and price transmission elasticity of 0.785
Real exchange rate	Per cap	-22.4	6.4	Price response of per capita demand to world price change using approximate price elasticity and price transmission elasticity of 0.785
Projected per capita demand	Per cap	30.0	29.7	Sum of income, world price, exchange rate effects on per capita demand, linearized approximation
Population	Total	35.3	35.3	Population shift, holding per capita demand constant
Projected total demand	Total	75.9	75.4	Combined estimated per capita and population effects (sum + product of relative changes)

Note: TSh = Tanzanian shilling.
Source: USDA, Economic Research Service

projections assume that all deciles experience similar economic and population growth over time, whereas fertility rates and income growth likely vary by decile.

The decomposition of demand growth per capita shows that the change in the real world price— after being scaled by the own-price elasticity and the price transmission elasticity—is the most significant contributor (14 percent) to per capita demand growth. The real appreciation of the Tanzanian currency, after proper scaling by elasticities, induces 6 percent of per capita demand growth, while income growth contributes 9 percent. The approximation of per capita demand growth misses less than 1 percent of projected growth, which is due to the interaction between price and income changes and from the linear approximation implied in equation (16). The latter shortfall is slightly accentuated in the total demand projection, which is about 0.4 percentage point of growth short of the projected change (75.88 percent versus 75.39 percent). Since food group quality scaling is normalized to 1 for aggregate demand in every year, the growth of total food demand is invariant to quality scaling.

Conclusion

This report presents a parsimonious modeling approach to incorporate price effects, quality variation, and consistent aggregation across income classes and food qualities in a food demand system. The approach can be used to assess calorie intake per income decile and to investigate income, price, and exchange rate shocks on food demand. It will be applied to improve USDA's *International Food Security Assessment* model.

The approach is based on a simple PIGLOG demand approach for four food categories (major grains, other grains, roots/tubers, and an aggregate for all other food). The approach, illustrated for Tanzania, relies on the data currently available for these assessments. In addition to identifying the food-insecure population and a country's distribution gap, the new approach can identify key drivers of food insecurity, like changes in population, income, world price, and real exchange rates.

The approach makes use of various USDA-ERS data products (elasticities estimates, macro data, past food security assessments, and international price outlook) and adds value to the portfolio of these products. The approach also incorporates information from national food surveys to better determine calorie availability per income decile using FAO's *State of Food Insecurity* (2014). Further household food survey data could be used when available and reliable. Alternative sources for consumption data as well as sensitivity analysis of the approach will be explored in future work.

References

Amikuzuno, Joseph, and Ogundari Kolawole. 2013. "Price Transmission Analysis and Associated Policy in Sub-Saharan Africa's Agricultural Markets: What Does the Literature Say?" Mimeo, presented at Fourth International AAAE Conference, Sept. 22-25, 2013, Hammamet,Tunisia.

Badiane, O., T. Makombe, and G. Bahiigwa (eds.). 2014. *Promoting Agricultural Trade to Enhance Resilience in Africa*. ReSAKSS Annual Trends and Outlook Repor,t 2013. International Food Policy Research Institute (IFPRI).

Beghin, John, Birgit Meade, and Stacey Rosen. 2014. "A consistent food demand framework for international food security assessment." Staff General Research Paper from Iowa State University, Department of Economics.

Campa, Jose Manuel, and Linda S. Goldberg. 2005. "Exchange rate pass-through into import prices," *Review of Economics and Statistics* 87(4): 679-690.

Cox, Thomas L., and Michael K. Wohlgenant. 1986. "Prices and quality effects in cross-sectional demand analysis," *American Journal of Agricultural Economics* 68.4: 908-919.

Deaton, Angus. 1988. "Quality, quantity, and spatial variation of price," *The American Economic Review* 78(3): 418-430.

Deaton, Angus. 1990. "Price elasticities from survey data: extensions and Indonesian results," *Journal of Econometrics*, *44*(3): 281-309.

Dong, Fengxia. 2006. "The outlook for Asian dairy markets: the role of demographics, income, and prices," *Food Policy* 31(3): 260-271.

Grunert, Klaus G. 2005. "Food quality and safety: consumer perception and demand," *European Review of Agricultural Economics* 32(3): 369-391.

Heien, Dale M., and Cathy Roheim Wessells. 1988. "The demand for dairy products: structure, prediction, and decomposition," *American Journal of Agricultural Economics* 70.2: 219-228.

Lewbel, Arthur. 1989. "Household equivalence scales and welfare comparisons," *Journal of Public Economics* 39.3: 377-391.

Minot, Nicholas. 2011. "Transmission of world food price changes to markets in Sub-Saharan Africa." Washington: International Food Policy Research Institute , IFPRI Discussion Paper 01059, Jan.

Muellbauer, John. 1975. "Aggregation, income distribution and consumer demand," *The Review of Economic Studies* 42.4: 525-543.

Muhammad, Andrew, James L. Seale, Birgit Meade, and Anita Regmi. 2011. *International Evidence on Food Consumption Patterns: An Update Using 2005 International Comparison Program Data* USDA, Economic Research Service, TB-1929. http://www.ers.usda.gov/publications/tb-technical-bulletin/tb1929.aspx

Mundlak, Yair, and Donald F. Larson. 1992. "On the transmission of world agricultural prices," *The World Bank Economic Review* 6(3): 399-422.

Shui, Shangnan, John C. Beghin, and Michael Wohlgenant. 1993. "The impact of technical change, scale effects, and forward ordering on U.S. fiber demands," *American Journal of Agricultural Economics* 75(3): 632-641.

Reardon, Thomas, and Elizabeth Farina. 2002. "The rise of private food quality and safety standards: illustrations from Brazil." *The International Food and Agribusiness Management Review* 4.4 (2001): 413-421.

Theil, Henri. 1967. *Economics and information theory*. Vol. 7. Amsterdam: North-Holland.

U.S. Department of Agriculture, Economic Research Service. 2012. *International Food Security Assessment*, *2012-22*, International Agriculture and Trade Outlook GFA-23 July.

U.S. Department of Agriculture, Economic Research Service. 2013. *International Food Security Assessment*, *2013-23*, International Agriculture and Trade Outlook GFA-24 June.

Van Rijswijk, Wendy, and Lynn J. Frewer. 2008. "Consumer perceptions of food quality and safety and their relation to traceability," *British Food Journal* 110(10): 1034-1046.

Yu, Xiaohua, and David Abler. 2009. "The demand for food quality in rural China." *American Journal of Agricultural Economics* 91(1): 57-69.