A Food Commodity Trend Projection Model with Application to East African Countries

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SUBMITTED TO
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Executive Summary

In April 2011, USAID/Africa Bureau commissioned the Worldwide Support for Trade Capacity Building (TCBoost) project (implemented by Nathan Associates Inc) to quantify and aggregate the most important trends affecting the supply and demand of food crops in the East African sub-region over the next ten years (2010-2020). The objective of the study was to better understand the medium-term supply and demand dynamics resulting from these agricultural trends in the region, and the implications for potential deficits or surpluses, by country and commodity, to guide USAID missions in making the right investments in the agricultural sector. A key deliverable of the research was an Excel-based projection model, showing key assumptions and including an interface to allow USAID to easily examine the effects of varying these assumptions. This paper describes the resulting model, the Food Commodity Trend Projection (FTP) model, as well as the key findings of the ten-year projections.

Projections of food commodity supply and demand in developing countries are essential for assessing trends in food energy supply, poverty, malnutrition, income, and other important economic outcomes. These assessments in turn influence evaluation of policy options, optimal investment allocation, and other important decisions. Projections of food trade flows also permit analysis of emerging trade patterns and potentialities and prospects for engagement with regional and global economies and the ability of trade in food to support development.

The Food Commodity Trend Projection (FTP) model is a simple and transparent tool that projects components of food commodity demand and supply for the period 2010-2020 at the level of individual countries in the East African region. 11 countries are included in and fully covered by the model: Burundi, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Uganda, and Zambia. Southern Sudan is partially included in the model. 21 food commodities are modeled separately: 6 cereal crops, 10 non-cereal crops, and 5 livestock products. These commodities cover the large majority of the agricultural sector and food basket in East African countries.

Projections are made using simple extrapolative techniques or, in the case of food consumption demand, a specification that captures simple behavioral relationships. Imports and exports are not projected separately: net exports of a commodity are calculated as the residual between domestic supply and demand (exclusive of trade flow.) Prices are not incorporated in the model, and all relative prices are implicitly assumed to stay constant over the projection period. The FTP model is completely transparent and permits its user to easily modify all key parameters that are used to make projections. Parameters are set at baseline values but can be changed by the user to run alternative scenarios.

The application of the FTP model to project supply and demand for 2010-2020 for the East African region produced some notable results, with direct implications for USAID- and other donor-funded agricultural capacity building programs. The baseline projection of commodity supply and demand in the East African region suggests that production growth for many commodities will not keep pace with consumption growth, and net exports will progressively fall through 2020, both in absolute terms and as a percentage of consumption. Divergence between production and consumption is due to declines in projected growth of area harvested, continued slow growth in yields, and significant acceleration in consumption due to faster real income per capita growth and high expenditure elasticities of demand for food commodities. If production of these food commodities does not expand more quickly than the baseline forecast, there will be pressure for food commodity inventories to fall and imports to rise, which may cause domestic food price levels to rise and current account balances to become more negative. Achieving more rapid growth in production will require stronger incentives to producers to increase yields and expand areas under cultivation. Baseline results emphasize the importance of initiatives and projects such as the Comprehensive Africa Agricultural Development Programme (CAADP) and the USG-sponsored Feed the Future program that promote improving agricultural productivity. The FTP model can be used to simulate the change in production growth that is necessary to result in a more regionally self-sufficient path of supply and demand for a commodity.

The model is also used to assess trends in net exports of countries neighboring Southern Sudan in order to identify commodities that might represent export opportunities for Southern Sudan in the future. The baseline projection identifies several crops and meats that are likely to be imported in large quantities by Southern Sudan's neighbors in 2020. However, Southern Sudan itself is projected to experience large deficits of cereals in 2020, and major improvements from baseline production projections will be needed if Southern Sudan is to both satisfy domestic demand and also export.

The development of the FTP model raises other potential areas for research and model development, including parameter refinement, extension and refinement of relationships between model variables, and new projection capabilities. Such developments include, for example:

- The commodity production function can be refined so as to explicitly incorporate inputs such as fertilizer, labor, machinery, and other factors that influence yield. Commodity production functions have been estimated using household survey data and are reported in an appendix, but more data is required in order to develop baseline yield forecasts using this approach;

- In countries for which the agricultural sector accounts for one-third or more of national income, there should be a feedback mechanism between agricultural performance and GDP growth. It might be possible to develop such a feedback mechanism in a simple manner.

- Optimistic yield growth scenarios can be developed by establishing yield projections based on evaluation of yield growth over the past two decades in low- and middle-income countries to identify top performers and determine an appropriate benchmark that East African countries might optimistically but realistically be expected to attain

Key Indicative Results

The Food Commodity Trend Projection (FTP) model is a tool for projecting components of food commodity demand and supply for the period 2010-2020 at the level of both an individual country and an aggregation of countries. The model has been developed using the historical data for countries in the East Africa region, which includes Burundi, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Southern Sudan, Tanzania, Uganda, and Zambia. 21 food commodities are modeled separately: 6 cereal crops (wheat, rice, maize, millet, sorghum, and "other cereals"), 10 non-cereal crops (potatoes, sweet potatoes, beans, peas, soybeans, groundnuts, sesame seeds, bananas, and plantains), and 5 livestock products (bovine meat, sheep and goat meat, pig meat, poultry meat, and milk.)

The food commodities included in this model account for the large majority of the agricultural production and food basket of East Africa. Table 1 gives data on the ratio of area harvested for the 16 crop commodities in the model to total crop area harvested for 2009 and the average value of this ratio during 1993-2009. Model crops accounted for 75% of the crop area harvested in the East Africa region on average during 1993-2009 and 76% in 2009. The ratio of the kilocalories per person per day provided by the food commodities included in the model to total kilocalories averaged 80% in 1993-2007 and in 2007.[1] There is a residual of crop and animal commodities used for food that are not included in the model (e.g. some fruits and vegetables, fish, and eggs), but these commodities account for a relatively small percentage of the food basket in terms of energy provided.[2]

The average level of energy provided as measured by FAO data on kilocalories per person per day does vary across countries of the East Africa region, ranging in 2007 from a low of 1,605 (Democratic Republic of the Congo and Eritrea) to 2,211 (Uganda.) A non-FAO source estimates the value for Southern Sudan in 2009 at 2,399, which would likely give it the highest level of

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[1] The area harvested and kilocalorie coverage ratios essentially did not vary during 1993-2009, ranging between 74-76% for area harvested and 79-81% for kilocalories.

[2] A potentially important growth sector for sub-Saharan agriculture in the future are non-traditional crops, most of which are not covered by this model. Appendix F reviews data on area harvested in non-traditional crops in east Africa during 1990-2009.

food energy consumption in the region. It is not clear to what degree the FAO values and the non-FAO value are comparable.[3]

Table 1
Model Coverage and Kilocalories/person/day Levels

	Ratio: commodities in model to total commodities				Level	
	Area harvested		Kilocalories per person per day		Kilocalories per person per day	
	1993-2009 average	2009	1993-2007 average	2007	1993-2007 average	2007
Burundi	90%	87%	86%	87%	1,695	1,685
Democratic Republic of the Congo	85%	86%	87%	88%	1,677	1,605
Eritrea	65%	68%	76%	79%	1,547	1,605
Ethiopia	63%	64%	68%	68%	1,776	1,980
Kenya	70%	74%	76%	77%	2,033	2,089
Malawi	78%	78%	85%	87%	2,039	2,172
Mozambique	74%	73%	87%	91%	1,943	2,067
Rwanda	90%	87%	87%	89%	1,904	2,085
Southern Sudan	na	na	na	na	na	2,399*
Tanzania	75%	80%	89%	89%	1,967	2,032
Uganda	86%	85%	81%	79%	2,255	2,211
Zambia	80%	79%	83%	83%	1,911	1,873
East Africa Region	75%	76%	80%	80%	1,883	1,949

Sources: All values calculated from FAO data except for Southern Sudan (see appendix E.)
**: the kilocalorie/person/day value for Southern Sudan is for 2009: see appendix E.*

The FTP model is completely transparent and can be used by anyone who understands its inputs and outputs. The model permits the user to input or modify all key parameters that are used to project model results. Subsequent sections of the report describe the model's technical details and how it can be used. This section reviews key results of the model's baseline projections to 2020 for the region. It then presents projection results for Southern Sudan and its neighboring countries to shed light on potential opportunities for Southern Sudanese food exports to potential regional trade partners.

[3] The Southern Sudan value comes from a 2009 household budget survey and is described in more detail in appendix E. The level of cereals consumption as measured in this survey has been implicitly contested in a recent assessment of food security in southern Sudan, which suggests a much lower level of consumption.

Baseline Projections for the East Africa Region: Key Indicative Results

The baseline model projections for food commodity supply and demand are based on parameter value assumptions that are fully documented in the spreadsheet itself. Many parameter values must be inputted into the model to generate projections, and these parameters are described in detail in the technical description of the model below. The macroeconomic assumptions that are made to generate baseline projections are documented in Table 2 below, which gives average or aggregate values for key macroeconomic projections for the East African region as a whole. Real GDP growth in 2009-2020 is projected by the IMF to accelerate from the average rate experienced in 1990-2009, and population growth is projected by the United Nations to decline, resulting in a significant acceleration in per capita real GDP growth from 1.3% to 4.5%. Growth in the urbanization rate (the ratio of urban to total population) is projected to accelerate slightly.

Table 3 summarizes historical and projected values of the East African average of annual per-capita consumption in kilograms of the model's commodities in 1990, 2009, and 2020. For many commodities, average annual growth of per-capita consumption in 2009-2020 is projected to increase substantially over the growth prevailing in 1990-2009. Accelerated consumption growth for many food commodities is not surprising given the projected acceleration in per capita real GDP growth and the high values of expenditure elasticities of demand for sub-Saharan African countries.[4]

Table 4 reveals a tension between trends in production and consumption of food commodities in the region. For many commodities, growth in production is not projected to accelerate: growth in area harvested is projected in a majority of cases to fall, and yield growth, which has historically been low, is not projected to change significantly. However, consumption growth is projected to accelerate, and a natural outcome of this is a fall in net exports, as more imports are required to fill an increasing gap between commodity supply and demand. Table 5 shows that this is what happens for most commodities: net exports decrease from 2009 to 2020, both in absolute value and as a percentage of production.

There are several ways that the agricultural economy can react to a trend of significantly falling net exports for a food commodity:

- Domestic prices can rise;
- Production can rise, through an increase in area harvested and/or yield;
- Growth in consumption and/or other domestic uses can be curtailed; or
- The country can maintain the status quo and increase imports, as long as increased imports can be financed.

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[4] See appendix D for details on expenditure elasticities of demand used in the projection model.

In a model that incorporates prices and solves for price equilibrium, domestic price would rise, and this would increase production and decrease consumption.[5] The FTP model does not incorporate prices and does not solve for market equilibrium.[6] The model implicitly assumes that the domestic producer and consumer prices of food commodities remain constant relative to each other and the prices of other goods and services over the projection period. However, the FTP model can be used to change baseline values for key parameters to determine what would be necessary to produce a particular time path for net exports. Projected growth in area harvested and/or yield can be changed to generate alternative paths for production, and projected real income growth and other parameters related to consumption can be changed to generate alternative paths for consumption.

Table 2

Macroeconomic Assumptions: Averages or Aggregates for East Africa Region

	Average annual growth		Level		
	1990-2009	2009-2020	1990	2009	2020
Real GDP	4.2%	7.2%			
Population	2.8%	2.5%	199 mil.	339 mil.	444 mil.
Real GDP per capita	1.3%	4.5%			
Urbanization rate	1.5%	1.8%	18%	24%	29%

Sources: 1990-2009 data from World Development Indicators database. 2009-2020 real GDP growth rates are IMF projections, population growth rates are United Nations projections, and urbanization rate is projected by Nathan Associates.

[5] The extent to which price and production would rise, and consumption fall, depends on the magnitude of the supply and demand elasticities with respect to price.

[6] General equilibrium models are significantly more complicated than the FTP model and require substantial resources and training to build and run competently. See appendix A for a review of existing food commodity projection models.

Table 3

*Consumption Per Capita of Food Commodities in the East Africa Region : Regional Averages**

	Kilograms per person per year			Average annual growth	
	1990	2009	2020	1990-2009	2009-2020
Bananas	10.6	16.0	19.6	2.2%	1.8%
Beans	6.5	7.2	9.8	0.5%	2.8%
Cassava	144.7	104.9	105.5	-1.7%	0.1%
Groundnuts	2.1	1.6	1.9	-1.4%	1.5%
Maize	50.6	50.2	64.7	0.0%	2.3%
Millet	3.5	3.6	4.6	0.0%	2.4%
Other cereals	5.5	7.3	10.3	1.5%	3.2%
Peas	0.8	1.2	1.6	2.2%	2.2%
Plantain	34.4	24.0	27.9	-1.9%	1.4%
Potato	9.4	15.9	20.6	2.8%	2.4%
Rice	5.3	7.7	10.9	1.9%	3.2%
Sesame seeds	0.6	0.4	0.5	-1.8%	1.7%
Sorghum	8.6	11.2	15.2	1.4%	2.8%
Soybean	0.4	0.3	0.4	-2.2%	2.4%
Sweet Potato	20.3	22.8	25.9	0.6%	1.2%
Wheat	12.1	17.8	23.5	2.1%	2.6%
Bovine meat	4.4	4.3	6.0	-0.2%	3.1%
Mutton/goat meat	1.5	1.3	1.7	-1.0%	2.8%
Pig meat	0.7	1.0	1.3	1.6%	2.7%
Poultry meat	1.3	1.0	1.4	-1.0%	2.9%
Milk	24.1	24.4	33.0	0.1%	2.8%

Sources: 1990 values calculated from FAO data; 2009 and 2020 values are projected by the FTP model.
**: Includes Burundi, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, , Tanzania, Uganda, and Zambia. Does not include South Sudan.*

Table 4

*Key Historical and Projected Growth Rates for Supply and Demand Components: East Africa Region**

	Average annual growth in:							
	Total area harvested		Average yield		Total production		Total consumption	
	1990-2009	2009-2020	1990-2009	2009-2020	1990-2009	2009-2020	1990-2009	2009-2020
Bananas	4.2%	2.2%	-0.4%	0.0%	4.1%	2.5%	5.1%	4.4%
Beans	3.3%	2.1%	-0.8%	0.2%	2.4%	2.3%	3.3%	5.4%
Cassava	0.4%	0.4%	1.4%	-0.2%	0.3%	0.4%	1.1%	2.6%
Groundnuts	1.6%	2.2%	0.3%	0.2%	1.8%	2.8%	1.4%	4.1%
Maize	1.9%	0.7%	0.9%	0.5%	2.8%	1.2%	2.8%	4.9%
Millet	2.6%	0.8%	0.8%	0.5%	2.9%	2.0%	2.9%	4.9%
Other cereals	4.1%	4.0%	0.7%	1.4%	6.1%	4.1%	4.4%	5.7%
Peas	4.1%	-0.1%	2.6%	0.7%	3.9%	1.3%	5.1%	4.8%
Plantain	-2.4%	0.0%	-0.5%	0.0%	0.5%	0.0%	0.9%	3.9%
Potato	5.7%	2.7%	-0.3%	0.6%	6.1%	3.6%	5.8%	4.9%
Rice	2.5%	1.8%	1.5%	1.3%	2.6%	2.4%	4.8%	5.8%
Sesame seeds	5.1%	3.2%	-0.4%	0.5%	7.0%	4.3%	1.0%	4.2%
Sorghum	2.8%	1.7%	0.2%	0.3%	3.8%	2.9%	4.3%	5.4%
Soybean	6.6%	1.2%	-0.7%	0.7%	7.4%	2.1%	0.5%	4.9%
Sweet Potato	2.7%	1.9%	0.5%	0.2%	4.9%	-0.2%	3.5%	3.7%
Wheat	4.5%	2.7%	0.5%	0.4%	5.8%	5.8%	5.0%	5.1%
Bovine meat	2.2%	2.4%	0.1%	0.1%	2.7%	2.6%	2.6%	5.7%
Mutton/goat meat	1.4%	1.4%	-0.1%	0.0%	1.6%	1.5%	1.8%	5.4%
Pig meat	3.9%	2.3%	0.2%	0.0%	4.5%	2.4%	4.5%	5.3%
Poultry meat	0.3%	0.7%	0.1%	0.0%	0.7%	0.7%	1.8%	5.5%
Milk	2.1%	1.6%	-0.2%	0.4%	3.3%	2.9%	2.9%	5.4%

Sources: 1990-2009 growth rates calculated from FAO data. 2009-2020 growth rates are projected by the FTP model.
**: See notes to table 3.*

Table 5

*Supply and Demand Components of Food Commodities in the East Africa Region: Regional Aggregate**

	Year	Production	Food Consumption	Seed Use	Feed Use	Processing Waste	Other Use	Net Exports	Net exports as % of production
		(1000 metric tons)							
Bananas	1990	3,349	2,098	0	0	961	287	4	0%
	2007	7,433	5,373	0	0	1,000	1,212	-152	-2%
	2020	9,485	8,702	0	0	1,178	1,631	-2,026	-21%
Beans	1990	1,893	1,299	100	13	0	252	398	21%
	2007	2,713	1,944	162	250	0	217	260	10%
	2020	3,801	4,331	137	29	0	308	-1,029	-27%
Cassava	1990	36,715	28,749	0	3,527	0	3,556	1,632	4%
	2007	37,490	34,595	0	4,915	0	1,896	-7,661	-20%
	2020	40,770	46,836	0	5,240	0	2,020	-13,771	-34%
Groundnuts	1990	702	413	86	52	169	35	-59	-8%
	2007	953	515	90	51	173	147	-33	-4%
	2020	1,332	840	126	60	242	268	-203	-15%
Maize	1990	11,558	10,056	259	542	164	637	100	1%
	2007	18,318	15,485	353	1,613	263	1,236	-1,230	-7%
	2020	22,468	28,719	410	1,778	352	1,247	-10,554	-47%
Millet	1990	1,072	703	21	71	223	82	-60	-6%
	2007	1,663	1,152	31	93	306	120	-40	-2%
	2020	2,289	2,050	36	113	378	148	-436	-19%
Other cereals	1990	1,046	1,094	43	0	0	57	-248	-24%
	2007	2,436	2,255	86	0	0	502	-731	-30%
	2020	5,011	4,590	106	0	0	1,138	-823	-16%
Peas	1990	178	163	13	0	0	10	-15	-8%
	2007	314	395	16	0	0	23	-166	-53%
	2020	427	707	16	0	0	28	-325	-76%
Plantain	1990	13,975	6,843	0	1,987	2,999	2,147	-1	0%
	2007	14,645	7,678	0	2,320	3,494	1,217	-64	0%
	2020	15,293	12,379	0	2,391	3,646	1,312	-4,164	-27%
Potato	1990	2,384	1,859	288	11	0	218	14	1%
	2007	6,737	4,909	631	800	0	807	-440	-7%
	2020	10,832	9,136	1,029	1,611	0	1,323	-2,267	-21%
Rice	1990	951	1,060	49	0	3	55	-196	-21%
	2007	1,498	2,360	79	0	6	104	-960	-64%
	2020	2,032	4,838	171	0	0	94	-3,049	-150%
Sesame seeds	1990	145	113	2	2	28	5	0	0%
	2007	413	139	6	140	80	11	44	11%
	2020	829	214	10	533	110	12	-51	-6%

Table 5 (continued)

*Supply and Demand Components of Food Commodities in the East Africa Region: Regional Aggregate**

	Year	Production	Food Consumption	Seed Use	Feed Use	Processing Waste	Other Use	Net Exports	Net exports as % of production
		(1000 metric tons)							
Sorghum	1990	2,362	1,714	42	42	484	170	-189	-8%
	2007	4,482	3,723	73	73	825	336	-957	-21%
	2020	6,571	6,750	91	87	732	393	-1,556	-24%
Soybean	1990	120	84	6	0	22	5	0	0%
	2007	371	88	15	25	142	15	78	21%
	2020	588	158	18	52	152	26	182	31%
Sweet Potato	1990	4,550	4,038	0	250	0	410	-243	-5%
	2007	10,316	7,332	0	817	0	742	-940	-9%
	2020	10,953	11,501	3	1,260	0	636	-2,453	-22%
Wheat	1990	1,248	2,399	60	0	0	98	-1,137	-91%
	2007	2,835	5,847	128	0	0	639	-4,126	-146%
	2020	6,766	10,430	199	0	0	1,528	-5,373	-79%
Yams	1990	871	878	na	na	na	na	-7	-1%
	2007	1,377	1,359	na	na	na	na	14	1%
	2020	1,927	2,650	na	na	na	na	-723	-38%
Bovine meat	1990	303	302	na	na	na	na	1	0%
	2007	400	394	na	na	na	na	6	1%
	2020	478	757	na	na	na	na	-279	-58%
Mutton/goat	1990	145	146	na	na	na	na	-1	-1%
	2007	310	314	na	na	na	na	-4	-1%
	2020	435	594	na	na	na	na	-159	-37%
Pig meat	1990	229	251	na	na	na	na	-23	-10%
	2007	247	312	na	na	na	na	-65	-26%
	2020	282	636	na	na	na	na	-354	-126%
Poultry meat	1990	4,847	4,793	na	na	na	na	-222	-5%
	2007	8,806	7,415	na	na	na	na	547	6%
	2020	12,357	14,670	na	na	na	na	-2,938	-24%
Milk	1990	2,362	1,714	42	42	484	170	-189	-8%
	2007	4,482	3,723	73	73	825	336	-957	-21%
	2020	6,571	6,750	91	87	732	393	-1,556	-24%

Sources: 1990-2009 values calculated from FAO data. 2009-2020 values are projected by the FTP model.
**: See notes to table 3.*

FOOD COMMODITY DEVELOPMENTS IN SOUTHERN SUDAN AND NEIGHBORING COUNTRIES

The FTP model can also be used to generate projections that might be useful for identifying emerging opportunities for food commodity trade. The new nation of Southern Sudan may have opportunities to export to neighboring countries if those countries are projected to have a rising level of imports, which would be reflected in a falling level of net exports. Neighbors of Southern Sudan that are included in the FTP model include the Democratic Republic of the Congo, Ethiopia, Kenya, and Uganda.[7] Table 6 gives aggregate net exports and consumption in 2020 for these countries of the FTP food commodities. Most commodities are projected to be in significant deficit in this region.

Table 6 also shows that for the five cereal crops for which projections can be made for Southern Sudan, net exports in 2020 are projected to be significantly negative in both absolute level and as a percentage of consumption.[8] The main reason for this is that the initial values of net exports in 2010 are already quite negative. In order for Southern Sudan to both satisfy domestic demand and also capitalize on regional export opportunities to neighboring countries, domestic production will need to expand much more rapidly than in the baseline forecast.

[7] Two neighbors that are not covered by the model are the Central African Republic and Sudan. Trade developments with Sudan may be significant for Southern Sudan, as the mechanized agricultural sector in Southern Sudan already apparently exports most of its production to Sudan (see appendix E.)

[8] There are two different values available for the level of total cereal consumption in Southern Sudan in 2009/2010 that are significantly different: see appendix E for details. Which value is chosen as the base for projections makes an important difference to results. We use the lower estimate of cereal consumption (the FAO/WFP value) for the projections summarized in table 6.

Table 6

Net Exports in 2020 of Food Commodities by Southern Sudan and its Neighbors (tons)

	Neighboring Countries*			Southern Sudan			
	Net exports	Consumption	(ratio)	Production	Net exports	Consumption	(ratio)
Maize	-7751558	16639991	-47%	217643	-545595	730700	-75%
Millet	-472241	1908090	-25%	32897	-274080	301887	-91%
Rice	-1514783	1835939	-83%	4786	-33039	37586	-88%
Sorghum	-1582050	6062173	-26%	905940	-2460723	3240536	-76%
Wheat	-3952291	8574759	-46%	16912	-38004	49148	-77%
Bananas	-969273	2977658	-33%				
Beans	-732427	2051217	-36%				
Cassava	-12169478	30087935	-40%				
Groundnuts	-242723	527857	-46%				
Peas	-375285	643005	-58%				
Plantain	-3193343	9172685	-35%				
Potatoes	-1485193	3073387	-48%				
Sesame seeds	-79136	186262	-42%				
Soybean	-28187	84216	-33%				
Sweet Potato	-2057283	5944200	-35%				
Bovine meat	-684575	2083492	-33%				
Mutton/goat meat	-290509	626250	-46%				
Pig meat	-84273	281343	-30%				
Poultry meat	-243971	367394	-66%				
Milk	-3696973	12204607	-30%				

Source: FTP model projections.

**: Sum of values for Democratic Republic of the Congo, Ethiopia, Kenya, and Uganda.*

Technical Overview

The East African Food Commodity Trend Projection (FTP) model is a tool for projecting components of food commodity demand and supply for the period 2010-2020 at the level of individual countries in the region. 11 countries are included in and fully covered by the model: Burundi, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Uganda, and Zambia. 21 food commodities are modeled separately: 6 cereal crops, 10 non-cereal crops, and 5 livestock products. Cereals include wheat, rice, maize, millet, sorghum, and "other cereals."[9] Non-cereal crops include potatoes, sweet potatoes, beans, peas, soyabeans, groundnuts, sesame seeds, bananas, and plantains. Livestock products include bovine meat, sheep and goat meat, pig meat, poultry meat, and milk. Southern Sudan is also included in the model, but available data only permits the development of projections for the 5 cereal crops.

Projections are made using simple extrapolative techniques or, in the case of food consumption demand, a specification that captures simple behavioral relationships. The one exception to this approach is trade in each commodity. Imports and exports are not projected separately: instead, net exports (exports minus imports) of a commodity are calculated as the residual between domestic supply and demand (exclusive of trade flow.)

The FTP model is completely transparent and permits its user to easily modify all key parameters that are used to make projections. Parameters are set at baseline values that are described in detail below. These values can be changed by the user, for example to run optimistic or pessimistic scenarios that reflect growth acceleration or deceleration in the trend of supply and demand components respectively.

The technical overview begins with a review of the historical data on food commodity supply and use that comprise the model's historical database. This is followed by a discussion of specific components of commodity supply and use and how they are projected into the period 2010-2020. Detailed technical information on these components and how they are projected are provided in several appendices. A User's Guide section then explains how to use the model by altering

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[9] "Other cereals" is significant for Eritrea and Ethiopia as it covers the important staple crop teff. It is not significant for other countries in the region. "Other cereals" does not include cereals such as barley, buckwheat, oats and rye, which are not significant crops in the east African region and are not included in the model.

parameter values and defining regional aggregates. The report concludes with a section on suggestions on future research and model development.

FAO FOOD COMMODITY DATA

The model projects time series on food commodity supply and demand components whose historical values are developed and published by the United Nations' Food and Agricultural Organization (FAO). The FAO makes these data available in FAOSTAT databases, which can be downloaded from the FAO's website. FAOSTAT collects and publishes data on commodity production, trade, and consumption in separate areas of its website. FAOSTAT also publishes "food balance sheets" that give data on all elements of supply and demand in an integrated and consistent framework. Food balance sheet data are available only at a greater lag than the other datasets and currently provide data through 2007. The database used for the projection model consists of time series for supply and demand components from the FAO food balance sheets for the period 1990-2007. Wherever possible, data was taken from the other FAO datasets on production, trade and consumption to these time series to 2008 or 2009. These values should be regarded as potentially subject to revision.

FAO collects data on food commodities from national statistical authorities, and much of the data in its databases were obtained from these authorities. For some commodities for some years, data on a particular supply or demand component was not provided by the national authority, and FAO had to estimate or impute a value. These instances are transparently documented in the FAO databases.

MODEL COMPONENTS

Food Commodity Supply

Supply of a commodity consists of domestic production and imports. Imports are not projected separately in this model, as net exports are determined as a residual. Domestic production is projected as the product of yield (tons per hectare) and harvested area (hectares planted to a commodity that is actually harvested.) This specification is standard for all food commodity projection models (see appendix A.)

Yield Projection

Yield is projected by assuming an average annual growth rate in the projection period. The model user can input any value that they desire for this growth rate. For each commodity in each country, baseline growth rates for yield are suggested that reflect the recent historical trend in that yield series. Baseline growth rates were determined through evaluation of the behavior of each country-commodity yield series during 1990-2009.[10]

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[10] If a yield series displayed no tendency to increase or decrease in the recent historical period, the baseline growth rate is set at zero. If yield displayed a consistent tendency to increase or decrease over the

Yields in sub-Saharan African agriculture have generally grown very slowly over the past two decades, and this is reflected in baseline yield growth rates. Sub-Saharan African yields may begin to converge to relevant best-performance standards in future, so that "yield gaps" begin to shrink. Yield convergence scenarios can be simulated in the model by inputting higher values for yield growth.[11] One area of potential future model development is to incorporate a "yield response function" that makes yield a function of determinants such as fertilizer, animal use, machinery use, rural labor, and other inputs. Appendix G develops empirical estimates of "yield response functions" for Nigeria and Tanzania using household survey data. However, lack of data on historical levels of yield determinants and an issue regarding the true size of yield response to fertilizer prevented making this operational in the current model (see appendix G).

For meat commodities, yield is units of meat per harvested animal. These yields are very stable over time compared to crop yields.

Harvested Area Projection

The model projects harvested area by assuming an average annual growth rate in the projection period. The model user can input any desired value for this growth rate. For each commodity in each country, a baseline growth rate is set for harvested area that reflects the historical trend in the 1990s and 2000s. The process for setting this growth rate is similar to that followed for determining baseline yield growth rates.[12] For some East African countries a land availability constraint needs to be taken into account (see below.)

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recent historical period, the growth trend in the yield is projected to 2020 using a regression that makes historical yield values a function of a linear time trend: the regression is used to project yield to 2020, and an implied annual average growth rate for the period 2009-2020 is calculated using the historical 2009 and projected 2020 values. In some cases, yield grew over part of the historical period but not during several years immediately prior to 2009: in these cases, the growth rate is set at zero. In several cases in which yield rose substantially in 2009 but this jump-shift was inconsistent with values in years immediately prior to 2009, the jump-shift is purged from the projection by using the 2008 yield value as a projection starting point.

[11] One approach to developing optimistic scenarios for yield growth in sub-Saharan agriculture would be to evaluate yield growth over the past two decades in low- and middle-income countries, identify top performers, and determine an appropriate benchmark that west African countries might optimistically but realistically be expected to attain. This is a simple approach to projecting change in the yield gap for a food commodity, which measures the distance that the current (average) producer is away from the maximum attainable yield under current technology and climate. Hertel (2010) reviews the literature that quantifies crop yield gaps in various countries and regions using more sophisticated techniques. The evidence suggests that yield gaps for rain-fed agriculture in Africa are very large. However, constraints related to poor market accessibility, poor infrastructure, high transport costs, and poor access to credit give African producers poor economic incentives to make the investments necessary to reduce yield gaps (see Hertel 2010, pp.21-25). Acceleration in yield growth above the baseline values of the model can thus be interpreted as achieving more rapid improvements in the economic incentives necessary to close yield gaps.

[12] It is important to note that the FAO provides historical data on harvested area for food commodities. These values are often inconsistent with the value of harvested area implied by data on yield and production We use historical values for harvested area that are calculated from yield and production data in order to stay internally consistent.

For meat commodities, the number of animals slaughtered for meat is used in lieu of harvested area. Livestock herd size and the ratio of slaughtered animals to herd size are projected based on historical average annual growth rates. Model users can modify the projection parameters as desired.[13]

An important issue on the supply side is whether a country is constrained by land availability. Some countries have a quite abundant supply of land that is not presently being used for agricultural purposes and could be expanded into, whereas other countries have little or no suitable unused land available. Appendix B reviews data on land that is potentially and actually used for agricultural purposes and shows that sub-Saharan countries are generally not highly constrained by land availability at the national level.[14] For East African countries, the data in appendix B suggest that Burundi and Rwanda are highly constrained.[15] This is reflected in the fact that total harvested area for Burundi has not grown over the period 1990-2009, and for Rwanda over the period 2001-2009 (after recovery from the civil war.) The FTP model does not include a formal constraint on land availability. However, model users should refrain from inputting harvested area growth rates for Burundi and Rwanda that lead to significant growth in total harvested area.[16]

Approaches used by other models to determine yields and harvested area are reviewed in appendix A. For yield, these approaches specify relationships that make yield a function of inputs such as labor, machinery, fertilizer, and an exogenous technological trend. For harvested area for crops, these approaches are typically based on a model of a representative farmer optimally allocating land to different crops in order to maximize profit.

In future model development activity, it would be worthwhile to evaluate more sophisticated yet transparent functions for yield and area harvested.[17]

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[13] Historical data on livestock herd sizes and yields are available from the FAO. Historical values for the number of animals slaughtered are calculated using these two series.

[14] It should be noted that appendix B considers data only at the national level, and that some countries with lower ratios than Burundi and Rwanda might nonetheless experience significant land constraints in particular agricultural regions (for example, Malawi and Kenya.) Internal migration may permit bringing unused land into production over time.

[15] Although Uganda has somewhat high ratios of actual to potential land, total harvested area rose fairly rapidly during 1990-2009, at over 2% per year on average. Uganda might therefore be approaching a land supply constraint.

[16] Baseline projections for total area harvested for the crop commodities covered by this model in Burundi and Rwanda show a rise from 2009 to 2020 of 7% and 13% respectively. Total area for these crop commodities rose during 1990-2009 by 23% and 25% for Burundi and Rwanda respectively. The significant slowdown in growth from the historical to the projection period is consistent with an overall land constraint starting to bind. Area harvested for these commodities was able to rise in the historical period presumably due to a shift of land away from crop commodities not covered by this model.

[17] We have used recent household surveys for Nigeria and Tanzania to estimate yield response functions. Appendix G summarizes this research and empirical results. Kibaara et al (2008) evaluate trends in

Influences of Weather and Climate on Production

The FTP model does not explicitly incorporate any role for the influence of weather and climate change on commodity production. It projects average trend into the future using historical values through 2009. The recent drought in some East African countries is thus not captured in baseline model projections, and any systematic change through 2020 in climate influences on production is also not captured. This is a relatively short time horizon, and impacts of climate change may not significantly change over this horizon. Baseline yield and area harvested projections are based on recent trends and do presumably project forward any influence of climate change on these variables that have manifested in the 2000s. Baseline values can be altered by the model user to simulate weather and climate impacts as long as the user can quantify the relationship between these influences and model variables.[18]

Food Commodity Use

Use of a commodity consists of consumption by domestic consumers, exports, use for seed, use for feed, processing waste, other uses, and change in stocks. Exports are not projected separately in this model, as net exports by crop and country are determined as a residual.

Consumption by Domestic Consumers

Consumption by domestic consumers is calculated as a residual in the historical FAO data and equals total supply minus all components of demand other than consumption. This residual includes both consumption of "primary commodities" by households and other domestic consumers, and consumption of "processed commodities." Primary commodities are commodities that have not undergone any significant processing, whereas processed commodities have undergone significant processing and are embodied in processed foods. It is important to note that this residual is only an approximation to the true level of final consumption of the commodity by households and other domestic consumers. Appendix C reviews this issue in detail and shows that the problem is related to commodities embodied in the imports and exports of processed foods.

To project consumption by domestic consumers, growth in consumption demand is determined as the product of growth in per capita real total household expenditures and the expenditure elasticity of demand for the commodity. Projected consumption demand is also broken down into two components: demand from rural consumers and demand from urban consumers. This requires having separate projections for total real income in the rural and urban sectors, separate

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agricultural productivity for major food commodities during 1997-2007 using panel survey data on households who are agricultural producers.

[18] Hertel et al (2010b) project the impact of climate-induced yield changes on poverty through 2030 in 15 developing countries (including several in the east African region) using the GTAP model and provide a review of current projections of the impact of climate change on yields for several commodities. IFPRI (2009) uses the IMPACT model to project the impacts of climate change on yields, production, prices, calorie availability, and child malnourishment through 2050. Cooper and Roe (2011) review evidence on climate-induced risk in sub-Saharan rainfed agriculture and suggest that producers in this region already face high levels of rainfall variability that climate change will affect on the margin.

projections for rural and urban population, and separate expenditure elasticities of demand for rural and urban households. Appendix D describes the approach to projecting consumption demand in technical detail and documents the sources of data on population and income projections and expenditure elasticities of demand.

The model user is free to change assumptions on projected growth rates in real income, total population, and the degree of urbanization (share of urban population to total population), expenditure elasticities of demand, and other relevant parameters (see appendix D for more details.)

As noted earlier, the FAO consumption residual is only an approximation to the true level of consumption of a commodity. Insufficient data is available to permit assessment of the level of the difference between true and approximated consumption, and how that difference might change over time. This issue is discussed in more detail in Appendix C.

Use for Seed

Use of crop commodities for seed is projected by multiplying harvested area by a seed use ratio. Historical values of the seed use ratio are calculated as the ratio of quantity used for seed to area harvested, and a projection of the ratio for 2009-2020 is developed using simple extrapolation techniques. Most historical seed use ratios are very stable and display no growth trend.

Use for Feed

Historical data on the use of crop commodities for animal feed is analyzed and projected into 2009-2020 using simple techniques. The historic ratio of feed use to production is evaluated to determine a ratio value that is then applied to projected production to get projected feed use.[19]

Processing Waste

FAO provides data on the quantity of a commodity used for “processing.” This is not the quantity of the commodity that is sent to the food processing industry for transformation into processed foods, but the amount of the commodity that is lost to waste during storage and distribution processes.[20] In the FTP model, the historic ratio of processing waste to production is evaluated to determine a ratio value that is then applied to projected production to get projected processing waste.[21]

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[19] Ratio values are usually stable around a mean level over a long horizon or in recent years, and an appropriate average is taken. Feed use is not related structurally to herd size: although data on herd size is available, extensive work would need to be done to determine how a particular commodity is distributed to different types of animals as feed. The FAO data also suggests that feed use is often estimated in an ad hoc manner as a percentage of production.

[20] See the “concepts and definitions” section of the FAO website for detail on what “waste” includes. The FAO often estimates waste as a fixed percentage of production plus imports minus change in stocks.

[21] Ratio values are generally stable around a mean level over a long horizon or in recent years, and an appropriate average is taken.

Other Utilizations

FAO also provides data on the quantity of a commodity that is demanded for "other utilizations." This data includes quantities of a food commodity used for non-food purposes (e.g. oil for soap), consumption by tourists, and pet food. Historical values for other utilizations appear to have been estimated by FAO as a fixed proportion of domestic production for most country-commodity cases. The 2007 value of the ratio of other utilizations to domestic production and projected values of domestic production are used to project values for other utilizations for 2008-2020.

Change in Stocks

The final component of demand is change in stocks of a food commodity. For many commodities in many countries, change in stocks typically equals zero or has positive and negative values that display no consistent pattern. In these instances, change in stocks is projected at a value of zero for 2009-2020. In a small number of instances, change in stocks exhibits sustained positive or negative values for several years through 2008: in these instances, it is projected at the mean level into 2009-2020.

Kilocalories Consumed Per Person Per Day

The FTP model also produces projections of kilocalories consumed per person per day that are associated with the 23 food commodities that are covered by the model.[22] A projection of total kilocalories is made by projecting the residual kilocalories associated with commodities not included in the model independently using simple extrapolation techniques.

Trade In a Food Commodity

As mentioned previously, net exports of a commodity are calculated as a residual and equal total domestic supply minus total domestic demand (exclusive of trade flows.) It is important to recognize that any systematic projection error in non-trade supply and demand components will be absorbed into the net exports projection. If, for example, the projection of consumption of wheat in Ethiopia is systematically too low, then the projection of net exports of wheat will be too high.

Historical values for net exports in the database are also calculated as total domestic supply minus total domestic demand (exclusive of trade flows.) In a significant number of instances, the value of net exports calculated using this formula does not equal the value of exports minus imports reported in the food balance sheets. The reasons for these inconsistencies in the historical FAO data are not clear. We use the formula in both the historical and projection periods to maintain consistency in the series.

[22] FAO provides country-commodity-specific conversion factors necessary to translate consumption of a commodity in kilograms into kilocalories of energy consumed.

Food Commodity Prices

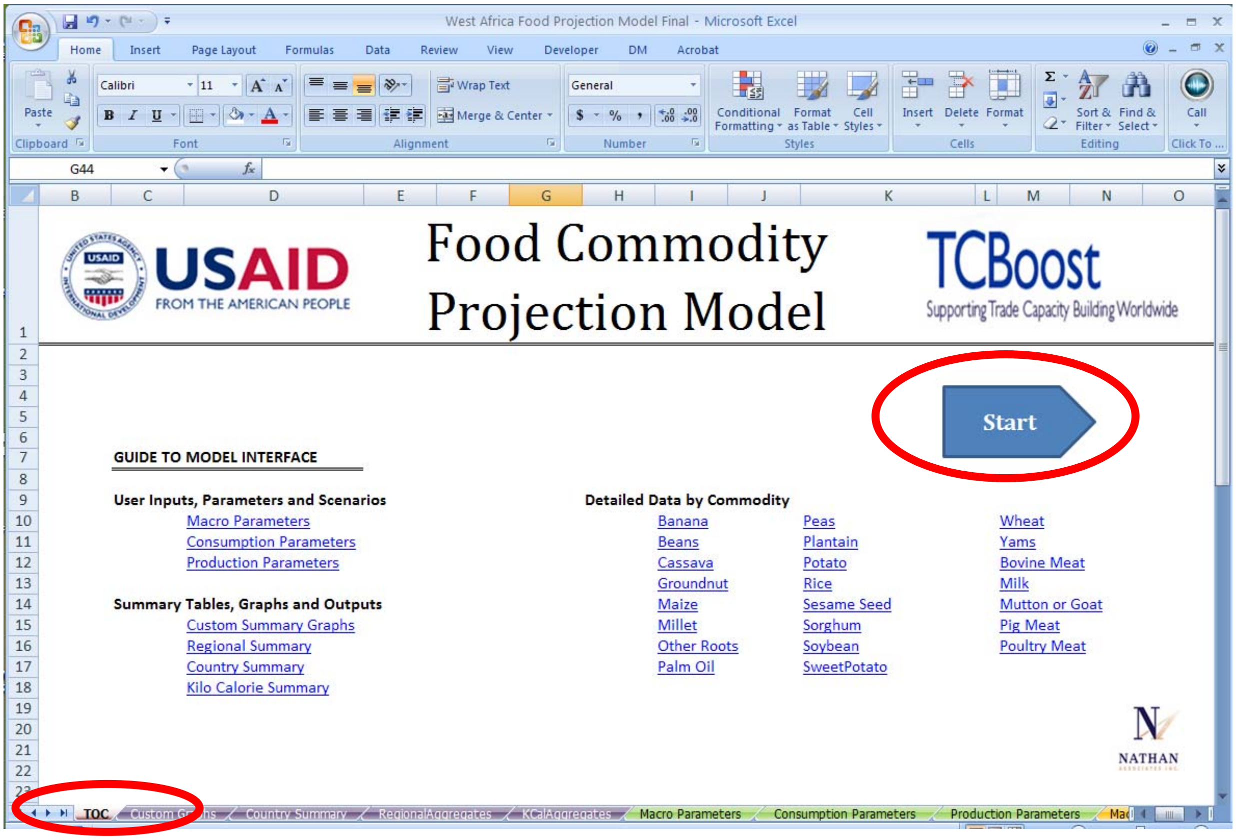
Existing food commodity models incorporate a role for prices such that change in a commodity's price affects the levels of supply and demand. Some of these models have price play the key role in bringing about equilibrium and model closure (see appendix A for more details.) The FTP model does not currently incorporate prices, for several reasons. First, we know of no compelling basis on which to project relative foodstuff prices exogenously, and this is required when prices are incorporated into a model but are not determined endogenously so as to bring about equilibrium between supply and demand. Second, incorporating prices requires a complete theoretical specification of consumer demand for a commodity and obtaining empirical values for the parameters of that specification. Finally, bringing prices into the model requires carefully modeling producer and consumer prices, related taxes, tariffs and subsidies, and transportation costs. Both of these would involve a significant increase in the complexity of the model, and obtaining empirical values for related parameters would be challenging. Bringing prices into the model could be an area of future model development but will require significant effort.[23]

23 Projections of world prices of food commodity groups (eg cereals, oilseeds) or key commodities (eg maize, wheat, rice) are available from studies that use general equilibrium models to project global agricultural outcomes. See Banse et al (2008) and Medvedev et al (2009) for illustrative examples, and Hertel (2010) for a review of key issues.

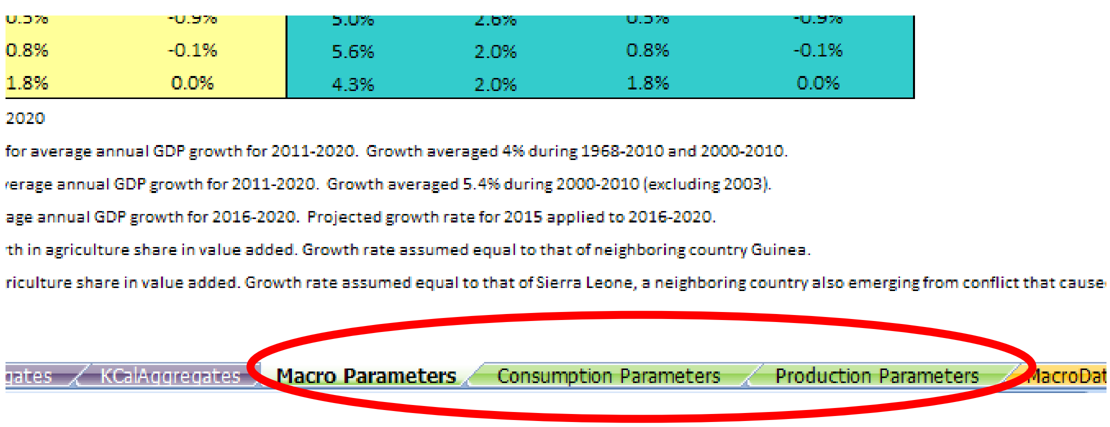
User's Guide

The Food Commodity Projection Model for East African countries consists of historic and projected values of food demand and supply components for 16 East African countries, and 23 food commodities. The database is created such that the user may modify parametric values of the projection data to gauge the impact of changing certain assumptions about agricultural commodity production and consumption in each of the sixteen countries. Default projection data use historic trends to project variable values to 2020. It is strongly recommended that the user save a copy of the original database as a separate file, before making modifications using their own parameters. The projection database is divided into four major blocks of worksheets: (i) the Guide Block; (ii) the Parameters Block; (iii) the Output Block; and the Data Block. The following sections describe each of these blocks and their component worksheets.

Guide Block (*red tab)*: This block consists of a single worksheet – "TOC," which serves as a central guide to the model interface. It includes links to each of the component worksheets in the remaining three blocks. To begin the process of reviewing the model's parameters, the user can click on the "Start" button in the upper right-hand side of this worksheet.

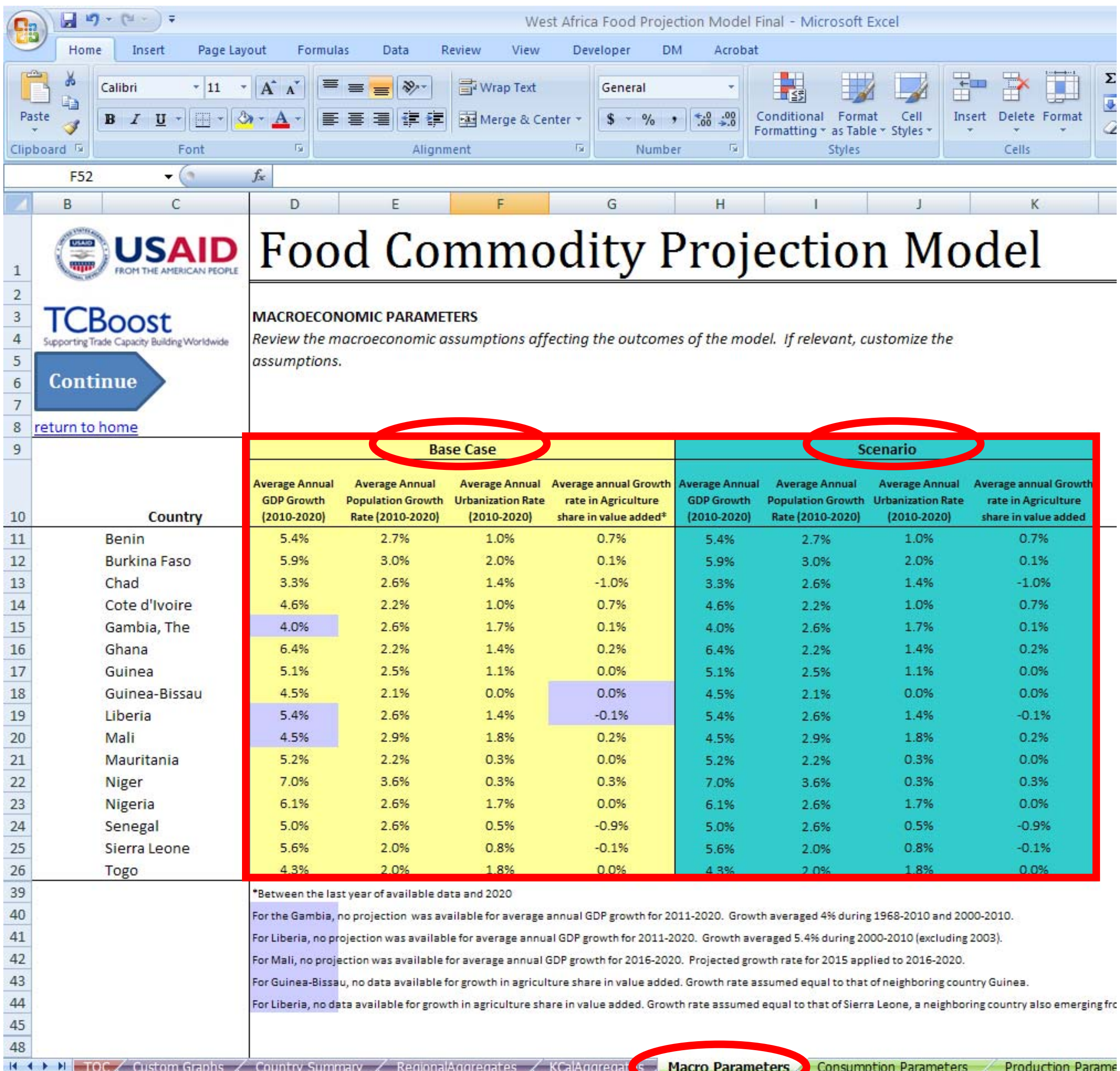


Parameters Block *(green tabs)*: Three worksheets constitute this block – “Macro Parameters”; “Consumption Parameters” and “Production Parameters”. These worksheets are linked to the projection data worksheets. Database users can modify the parameters used for projecting food commodity demand and supply using the cells in these worksheets. Two sets of parameters are presented on each of these worksheets – one for the base case and one for a scenario case. This enables the user to examine the way changes in the parameters affects the projections estimated in the model.



“Macro Parameters” tab: This tab consists of a small set of parameters that are linked to the “MacroData” worksheet. The parameters that can be changed in this worksheet relate to the macroeconomic and demographic features of each country. These parameters include: (i) average annual GDP growth (2010-2020); (ii) average annual population growth rate (2010-2020); (iii) average annual urbanization rate (2010-2020); and (iv) average annual growth rate in agriculture share in value added. Two sets of macro parameters are included. The set of parameters on the left hand side, in the yellow cells, are the base parameters, which have been estimated on the basis of historical trends. The set of parameters on the right hand side, in the green cells, are the scenario parameters. For those countries without adequate historical data to estimate the parameters, notes at the bottom of the table of parameters explain the projection technique employed.

In the "MacroParameters" tab, a user may change any of the existing parametric values for the given variables for one or more of the sixteen countries. All changes are automatically reflected the linked datasheets.



Country	Base Case: Average Annual GDP Growth (2010-2020)	Base Case: Average Annual Population Growth Rate (2010-2020)	Base Case: Average Annual Urbanization Rate (2010-2020)	Base Case: Average annual Growth rate in Agriculture share in value added*	Scenario: Average Annual GDP Growth (2010-2020)	Scenario: Average Annual Population Growth Rate (2010-2020)	Scenario: Average Annual Urbanization Rate (2010-2020)	Scenario: Average annual Growth rate in Agriculture share in value added
Benin	5.4%	2.7%	1.0%	0.7%	5.4%	2.7%	1.0%	0.7%
Burkina Faso	5.9%	3.0%	2.0%	0.1%	5.9%	3.0%	2.0%	0.1%
Chad	3.3%	2.6%	1.4%	-1.0%	3.3%	2.6%	1.4%	-1.0%
Cote d'Ivoire	4.6%	2.2%	1.0%	0.7%	4.6%	2.2%	1.0%	0.7%
Gambia, The	4.0%	2.6%	1.7%	0.1%	4.0%	2.6%	1.7%	0.1%
Ghana	6.4%	2.2%	1.4%	0.2%	6.4%	2.2%	1.4%	0.2%
Guinea	5.1%	2.5%	1.1%	0.0%	5.1%	2.5%	1.1%	0.0%
Guinea-Bissau	4.5%	2.1%	0.0%	0.0%	4.5%	2.1%	0.0%	0.0%
Liberia	5.4%	2.6%	1.4%	-0.1%	5.4%	2.6%	1.4%	-0.1%
Mali	4.5%	2.9%	1.8%	0.2%	4.5%	2.9%	1.8%	0.2%
Mauritania	5.2%	2.2%	0.3%	0.0%	5.2%	2.2%	0.3%	0.0%
Niger	7.0%	3.6%	0.3%	0.3%	7.0%	3.6%	0.3%	0.3%
Nigeria	6.1%	2.6%	1.7%	0.0%	6.1%	2.6%	1.7%	0.0%
Senegal	5.0%	2.6%	0.5%	-0.9%	5.0%	2.6%	0.5%	-0.9%
Sierra Leone	5.6%	2.0%	0.8%	-0.1%	5.6%	2.0%	0.8%	-0.1%
Togo	4.3%	2.0%	1.8%	0.0%	4.3%	2.0%	1.8%	0.0%

*Between the last year of available data and 2020

For the Gambia, no projection was available for average annual GDP growth for 2011-2020. Growth averaged 4% during 1968-2010 and 2000-2010.

For Liberia, no projection was available for average annual GDP growth for 2011-2020. Growth averaged 5.4% during 2000-2010 (excluding 2003).

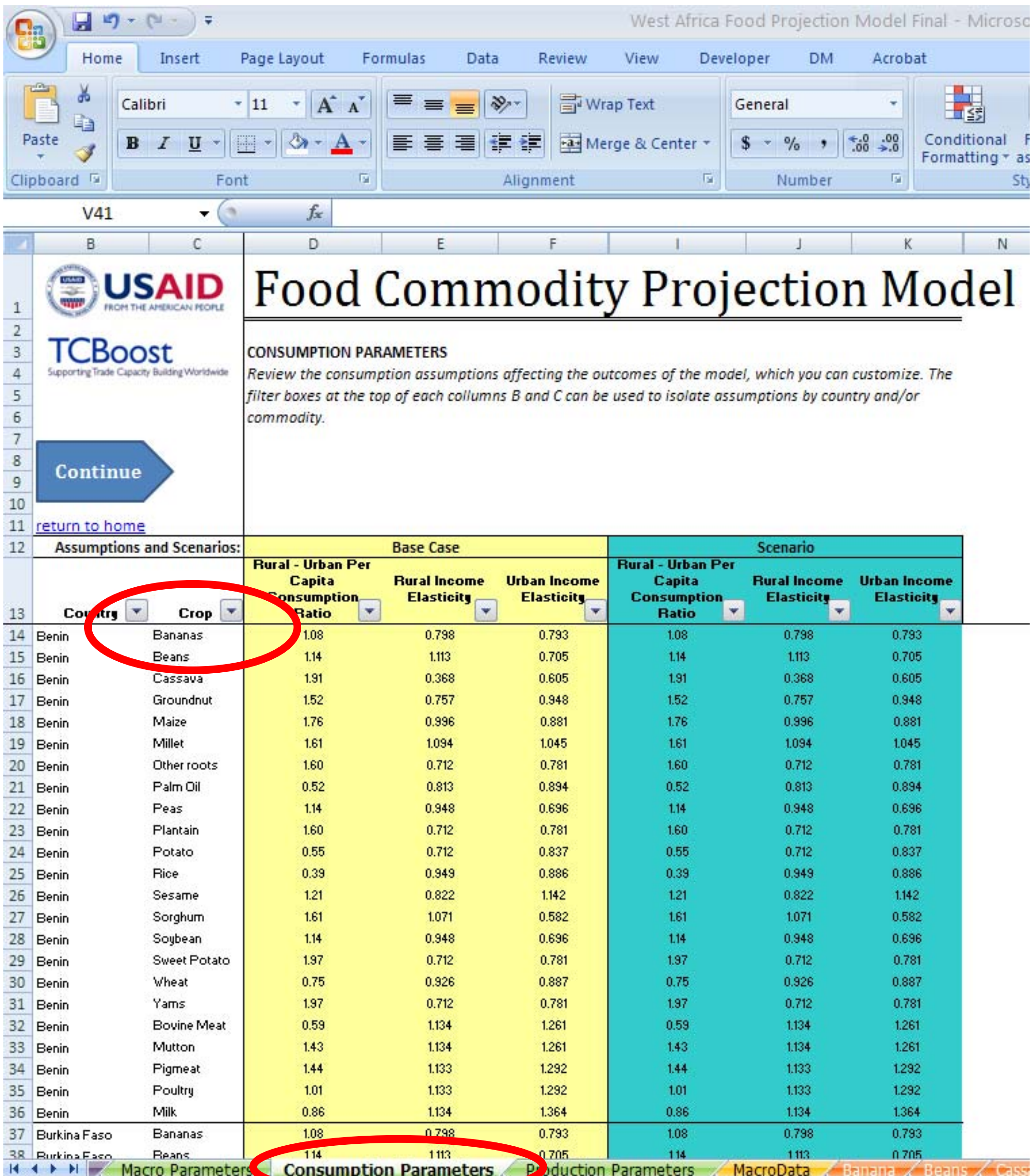
For Mali, no projection was available for average annual GDP growth for 2016-2020. Projected growth rate for 2015 applied to 2016-2020.

For Guinea-Bissau, no data available for growth in agriculture share in value added. Growth rate assumed equal to that of neighboring country Guinea.

For Liberia, no data available for growth in agriculture share in value added. Growth rate assumed equal to that of Sierra Leone, a neighboring country also emerging fr

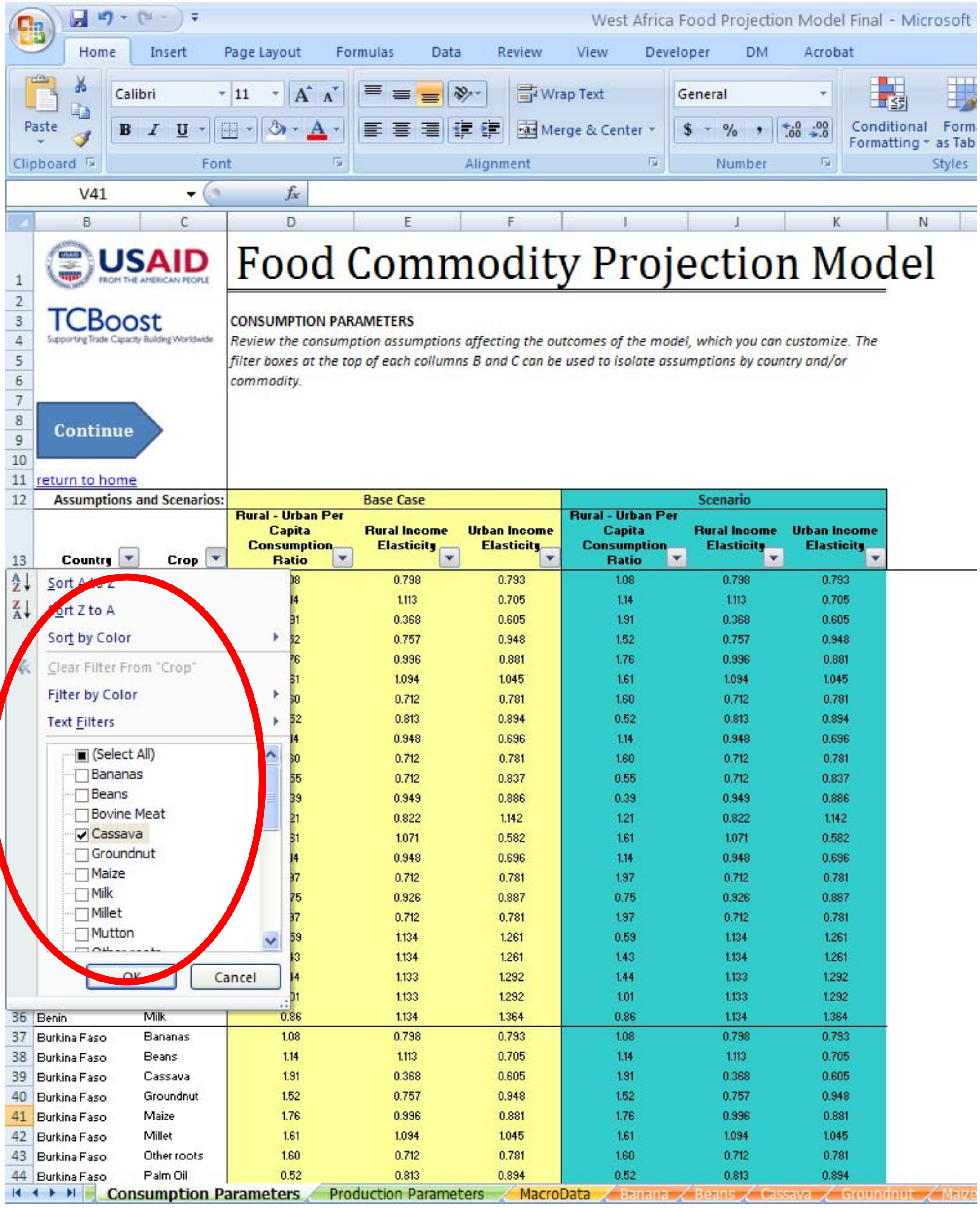
"Consumption Parameters" tab: This sheet contains parameters for each commodity and each country that the user can manually change to gauge the effect on crop demand. Parameters that can be changed for each crop and each country include: (i) rural-urban per capita consumption ratio; (ii) rural expenditure elasticity; and (iii) urban expenditure elasticity. As with the macro-parameters, the user can modify these parameters for both the base case and the scenario. Drop-down menus in this worksheet allow the users to modify parameters for one or more countries and/or one or more commodities. If a cell in this worksheet is empty, it is not linked to the data sheets either because there is no historic data to establish a parameter, or because the parameter does not adequately explain historic trends.

In the example below, a user would like to change the parametric assumptions used to project the demand of cassava in all countries.

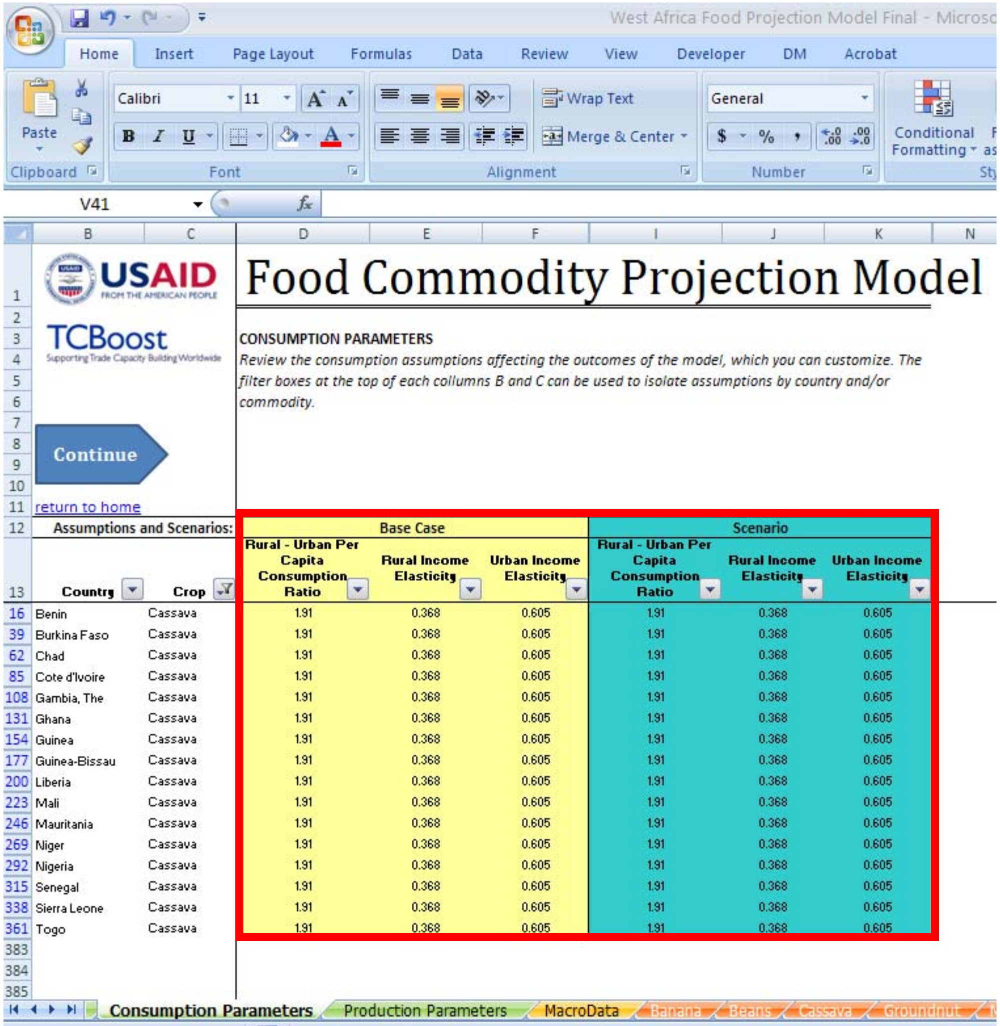


Assumptions and Scenarios:		Base Case			Scenario		
Country	Crop	Rural - Urban Per Capita Consumption Ratio	Rural Income Elasticity	Urban Income Elasticity	Rural - Urban Per Capita Consumption Ratio	Rural Income Elasticity	Urban Income Elasticity
Benin	Bananas	1.08	0.798	0.793	1.08	0.798	0.793
Benin	Beans	1.14	1.113	0.705	1.14	1.113	0.705
Benin	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Benin	Groundnut	1.52	0.757	0.948	1.52	0.757	0.948
Benin	Maize	1.76	0.996	0.881	1.76	0.996	0.881
Benin	Millet	1.61	1.094	1.045	1.61	1.094	1.045
Benin	Other roots	1.60	0.712	0.781	1.60	0.712	0.781
Benin	Palm Oil	0.52	0.813	0.894	0.52	0.813	0.894
Benin	Peas	1.14	0.948	0.696	1.14	0.948	0.696
Benin	Plantain	1.60	0.712	0.781	1.60	0.712	0.781
Benin	Potato	0.55	0.712	0.837	0.55	0.712	0.837
Benin	Rice	0.39	0.949	0.886	0.39	0.949	0.886
Benin	Sesame	1.21	0.822	1.142	1.21	0.822	1.142
Benin	Sorghum	1.61	1.071	0.582	1.61	1.071	0.582
Benin	Soybean	1.14	0.948	0.696	1.14	0.948	0.696
Benin	Sweet Potato	1.97	0.712	0.781	1.97	0.712	0.781
Benin	Wheat	0.75	0.926	0.887	0.75	0.926	0.887
Benin	Yams	1.97	0.712	0.781	1.97	0.712	0.781
Benin	Bovine Meat	0.59	1.134	1.261	0.59	1.134	1.261
Benin	Mutton	1.43	1.134	1.261	1.43	1.134	1.261
Benin	Pigmeat	1.44	1.133	1.292	1.44	1.133	1.292
Benin	Poultry	1.01	1.133	1.292	1.01	1.133	1.292
Benin	Milk	0.86	1.134	1.364	0.86	1.134	1.364
Burkina Faso	Bananas	1.08	0.798	0.793	1.08	0.798	0.793
Burkina Faso	Beans	1.14	1.113	0.705	1.14	1.113	0.705

He/She would select "Cassava" from the drop-down menu under "Crop".

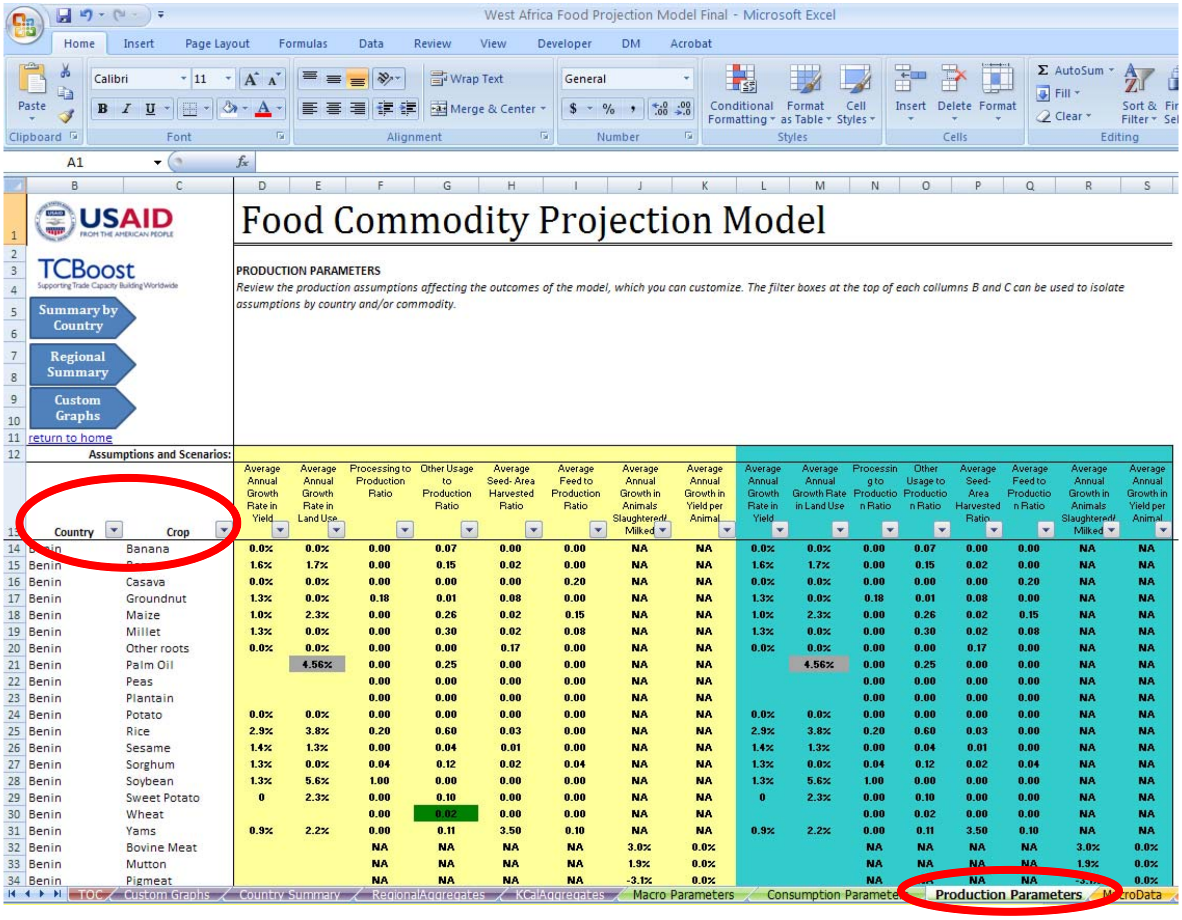


He/She could then change any of the parametric assumptions used to project the demand of "Cassava" in one or more of the sixteen East African countries. Note: Only those parameters for which data already exists in the database can be changed.



Assumptions and Scenarios:		Base Case			Scenario		
Country	Crop	Rural - Urban Per Capita Consumption Ratio	Rural Income Elasticity	Urban Income Elasticity	Rural - Urban Per Capita Consumption Ratio	Rural Income Elasticity	Urban Income Elasticity
Benin	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Burkina Faso	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Chad	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Cote d'Ivoire	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Gambia, The	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Ghana	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Guinea	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Guinea-Bissau	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Liberia	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Mali	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Mauritania	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Niger	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Nigeria	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Senegal	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Sierra Leone	Cassava	1.91	0.368	0.605	1.91	0.368	0.605
Togo	Cassava	1.91	0.368	0.605	1.91	0.368	0.605

"Production Parameters" tab: This sheet contains parameters for each commodity and each country that the user can manually change to gauge the effect on crop supply and types production. Parameters that can be changed for each commodity and each country include: (i) average annual growth rate in yield; (ii) average annual growth rate in land use; (iii) processing to production ratio; (iv) other usage to production ratio; (v) average seed-area harvested ratio; (vi) average feed to production ratio; (vii) average annual growth in animals slaughtered/milked and (viii) average annual growth in yield per animal. As with the other parameters, the user can modify these parameters for both the base case and the scenario. Also, similar to the consumption parameters, drop-down menus in this worksheet allow the users to modify parameters for one or more countries and/or one or more commodities. If a cell in this worksheet is marked "NA", it is not linked to the data sheets because it is not relevant to a given commodity.

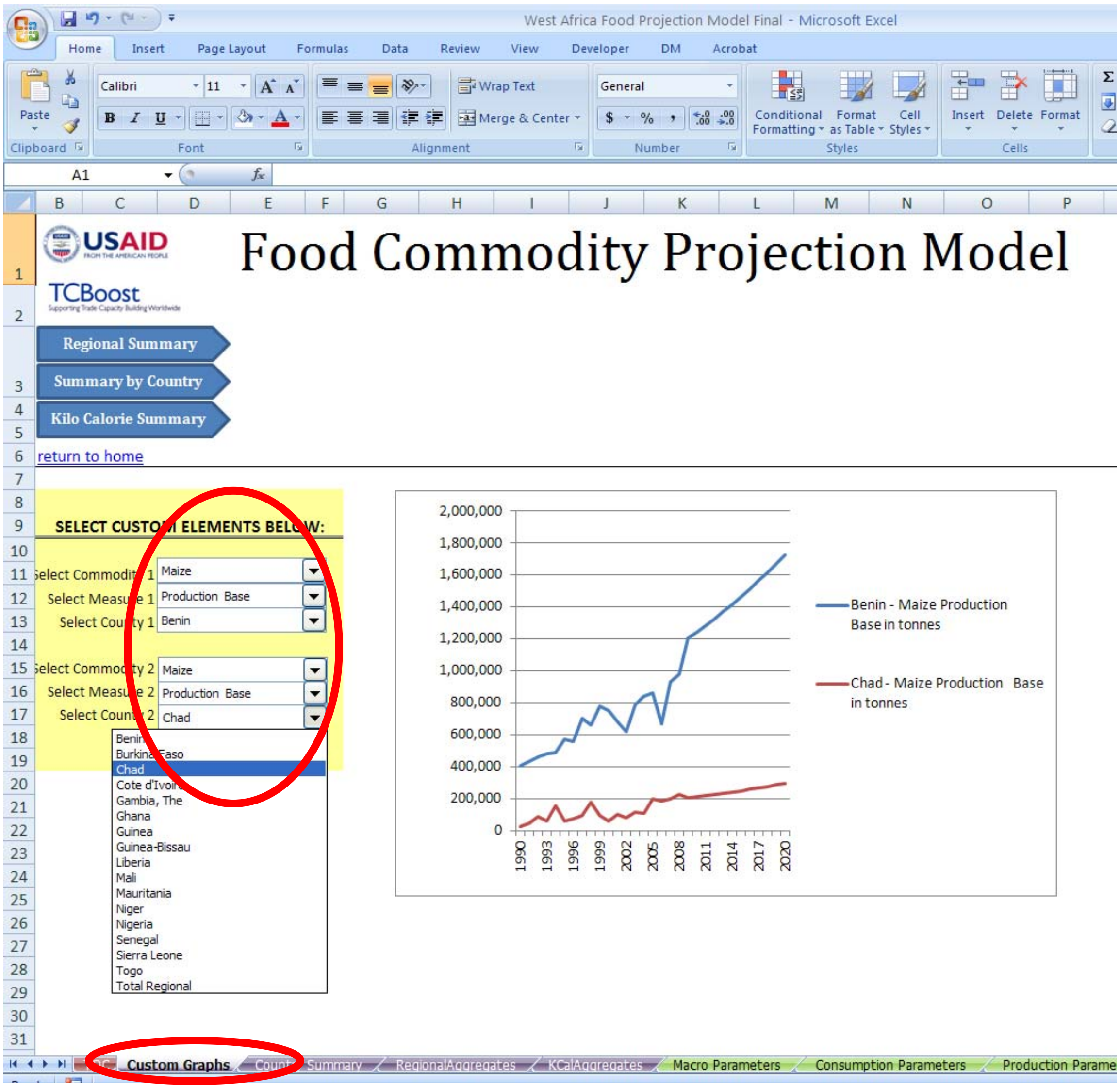


In the "Production Parameters" tab, a user may change any of the parametric assumptions used to project the production for any of the twenty-three commodities and the sixteen countries included in the model. For an explanation of how to isolate the parameters for a single country or commodity, please refer to the instructions for the "Consumption Parameters" tab.

Output Block *(purple tabs)*: The output block consists of graphs or summary tables that the user can build using the data from the data block. This block consists of four worksheets—"Custom Graphs"; "Country Summary"; "Regional Aggregates"; and "Kcal Aggregates". In addition, there are also two hidden tabs in the file, data from which provide inputs into the data block.

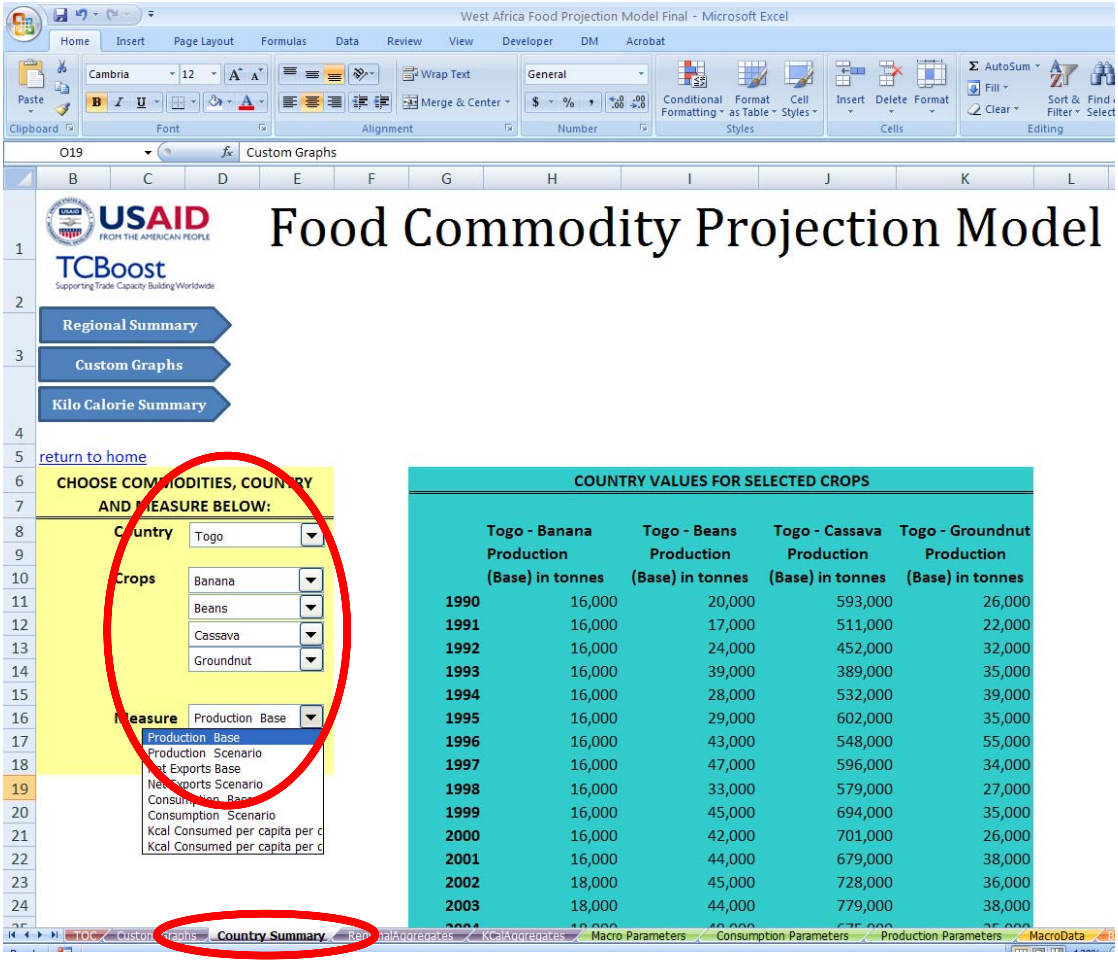
"Custom Graphs" tab: This sheet allows users to choose two combinations of commodities, measures, and countries, and to examine their trends over time. The user can select from a series of drop down menus the commodities, measures and countries they would like to view. For example, this worksheet might be used to visualize the difference in consumption and production of a given commodity in a single country. Alternatively, it might be used to compare production of a commodity between different countries. It can also be used to compare the base case and scenario.

In the example below, a user would like to view the difference between Maize production in Benin and Chad.



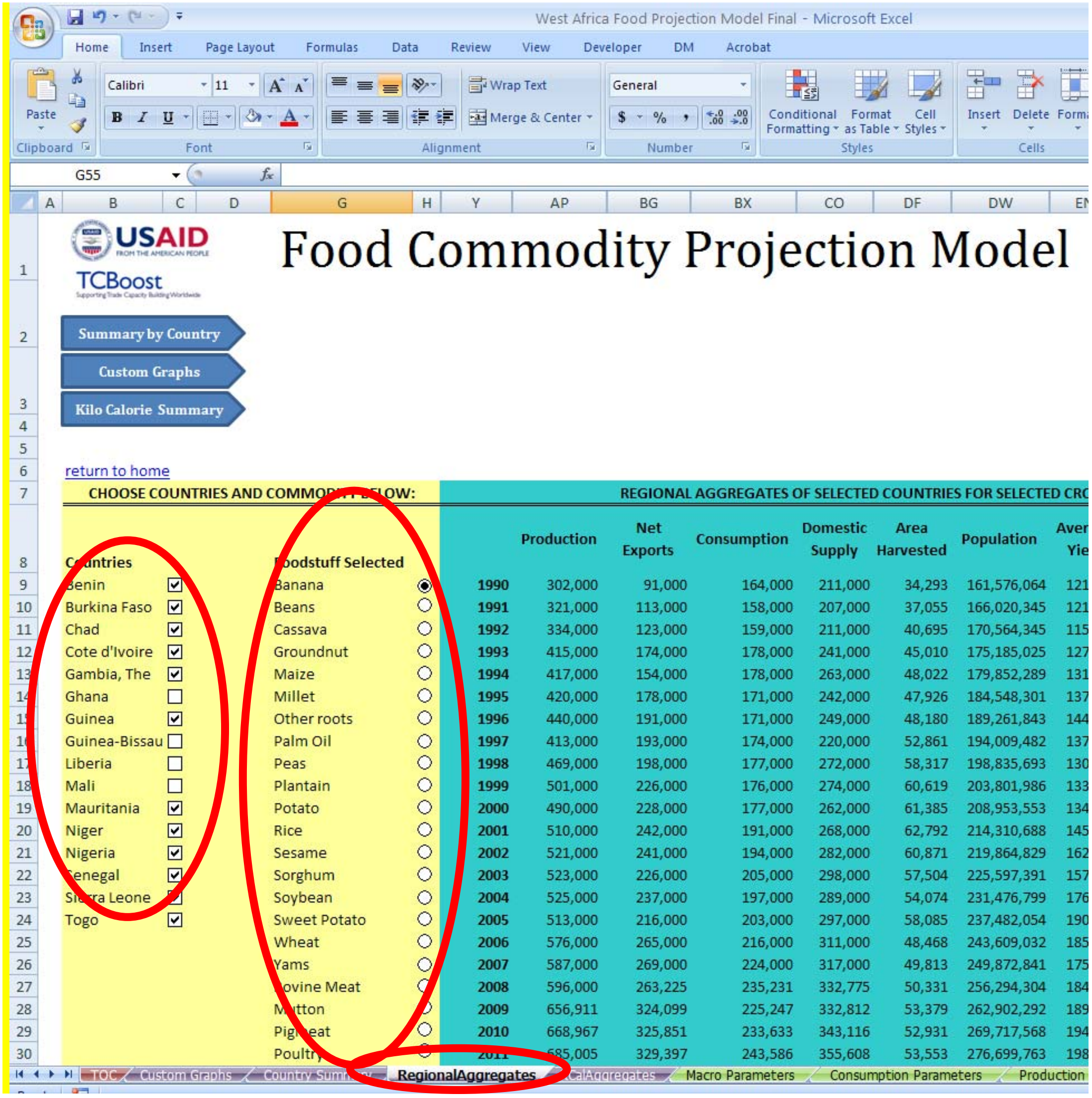
"Country Summary" tab: This sheet allows users to choose a particular country and measure to view historical data and projections for a subset of commodities. The available measures include: (i) production base; (ii) production scenario; (iii) net exports base; (iv) net exports scenario; (v) consumption base; (vi) consumption scenario; (vi) kcal consumed per capita per day base; and (vii) kcal consumed per capita per day scenario.

In the "Country Summary" tab, a user may select one country, for which he/she would like to see projections for a given measure. He/she may select up to four commodities through a series of drop down menus. The cells shaded in yellow are for the selections. The cells shaded in blue automatically show the results of the selected regions' aggregations. The example below shows base case historical data and projections for banana, bean, cassava and groundnut production in Togo.



"Regional Aggregates" tab: This sheet allows users to choose a particular commodity and a subset of countries to aggregate values of production, consumption, regional net exports, domestic supply, average yield, and average kilocalorie consumption per person per year.

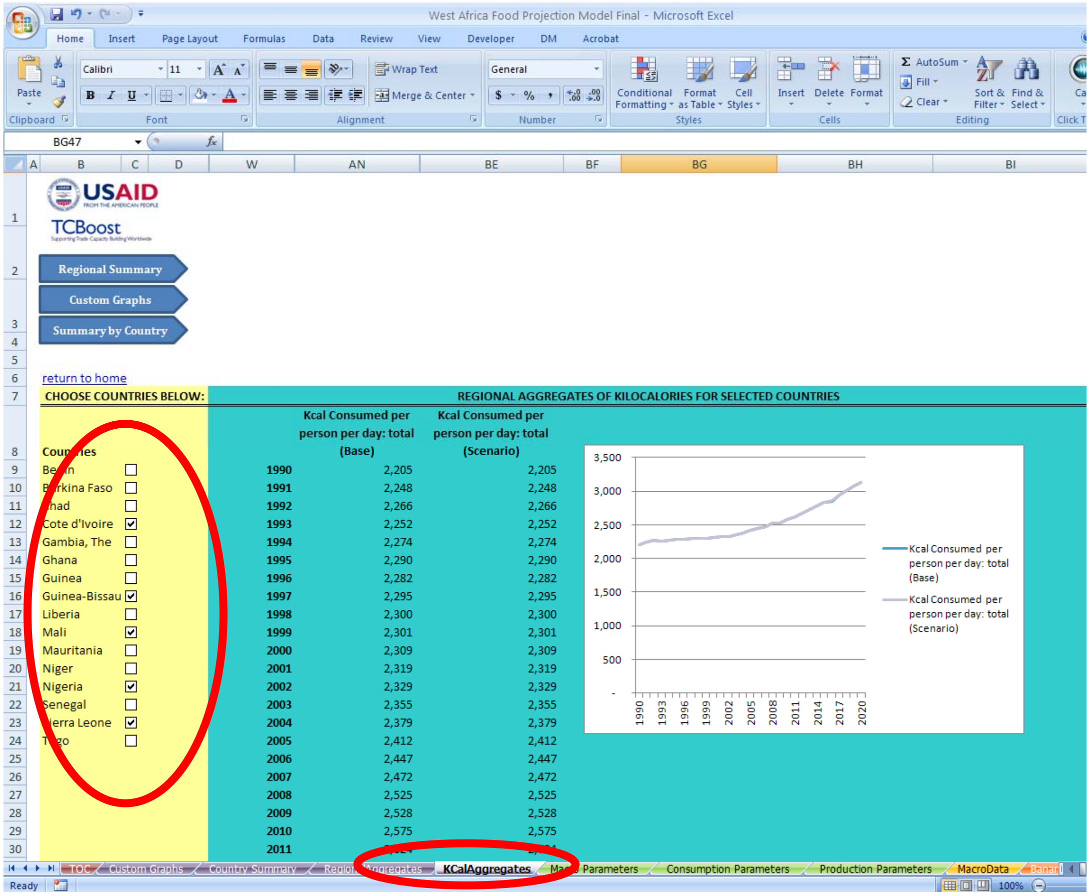
In the "RegionalAggregates" tab, a user may select one commodity, for which he/she would like to see regional aggregations. He/she may select two or more countries for which the regional aggregation is desired. The cells shaded in yellow are for the selections. The cells shaded in blue automatically show the results of the selected regions' aggregations.



	Production	Net Exports	Consumption	Domestic Supply	Area Harvested	Population	Aver Yie
1990	302,000	91,000	164,000	211,000	34,293	161,576,064	121
1991	321,000	113,000	158,000	207,000	37,055	166,020,345	121
1992	334,000	123,000	159,000	211,000	40,695	170,564,345	115
1993	415,000	174,000	178,000	241,000	45,010	175,185,025	127
1994	417,000	154,000	178,000	263,000	48,022	179,852,289	131
1995	420,000	178,000	171,000	242,000	47,926	184,548,301	137
1996	440,000	191,000	171,000	249,000	48,180	189,261,843	144
1997	413,000	193,000	174,000	220,000	52,861	194,009,482	137
1998	469,000	198,000	177,000	272,000	58,317	198,835,693	130
1999	501,000	226,000	176,000	274,000	60,619	203,801,986	133
2000	490,000	228,000	177,000	262,000	61,385	208,953,553	134
2001	510,000	242,000	191,000	268,000	62,792	214,310,688	145
2002	521,000	241,000	194,000	282,000	60,871	219,864,829	162
2003	523,000	226,000	205,000	298,000	57,504	225,597,391	157
2004	525,000	237,000	197,000	289,000	54,074	231,476,799	176
2005	513,000	216,000	203,000	297,000	58,085	237,482,054	190
2006	576,000	265,000	216,000	311,000	48,468	243,609,032	185
2007	587,000	269,000	224,000	317,000	49,813	249,872,841	175
2008	596,000	263,225	235,231	332,775	50,331	256,294,304	184
2009	656,911	324,099	225,247	332,812	53,379	262,902,292	189
2010	668,967	325,851	233,633	343,116	52,931	269,717,568	194
2011	685,005	329,397	243,586	355,608	53,553	276,699,763	198

"Kcal Aggregates" tab: This sheet allows users a subset of countries to view aggregate values of kilocalorie consumption per person per year. The table displays estimates for both the base case and scenario.

In the "Kcal Aggregates" tab, a user may select one or a combination of countries for which he/she would like to see regional aggregations. The cells shaded in yellow are for the selections. The cells shaded in blue automatically show the results of the selected regions' aggregations.



Data Block *(orange tabs)*: The worksheets included in this block are – "MacroData", which has macroeconomic and demographic data and projections; and a separate worksheet for each of the twenty-three commodities in our database including those for banana, beans, cassava, groundnuts, maize, millet, other roots, palm oil, peas, plantain, potato, rice, sesame seed, sorghum, soybean, sweet potato, wheat, yams, bovine meat, mutton, pig meat, poultry, and Milk. Data in these sheets should not be changed directly. However, projection data can be changed using the entries in one of the parameter block worksheets.

Areas for Future Research and Model Development

The development of the FTP model raises other potential areas for research and model development, including parameter refinement, extension and refinement of relationships between model variables, and new projection capabilities. Such developments include, for example:

- The commodity production function can be refined so as to incorporate a yield response function that makes yield a function of inputs such as fertilizer, labor, and machinery. Yield response functions have been estimated using household survey data and are reported in appendix G, but more data is required in order to develop baseline yield forecasts using this approach;

- In countries for which the agricultural sector accounts for one-third or more of national income, there should be a feedback mechanism between agricultural performance and GDP growth. It might be possible to develop such a feedback mechanism in a simple manner.

- Optimistic yield growth scenarios can be developed by establishing yield projections based on evaluation of yield growth over the past two decades in low- and middle-income countries to identify top performers and determine an appropriate benchmark that East African countries might optimistically but realistically be expected to attain.

Appendix A. Review of Food Commodity Forecasting Models

The three existing models of food commodity supply and demand that are reviewed here are:[24]

- The Food Security Assessment (FSA) model of the U.S. Department of Agriculture;
- The IMPACT model of the International Food Policy Research Institute (IFPRI);
- The IHS-GI model of the Global Harvest Initiative.

The FSA model does not model individual commodities but three commodity aggregates: grains, root crops, and "other" which includes all other commodities consumed (these aggregates are expressed in grain equivalent.) The FSA model covers 70 lower-income countries, including the countries covered by the FTP model. The IMPACT model covers 115 regions and countries and models all individual countries in Africa separately. 30 commodities and commodity aggregations are covered that correspond closely to the commodities modeled in FTP. The IHS-GI model covers a set of food commodities that is in some cases more aggregated than that of the FTP model. Results are reported for 7 regional groupings of countries (including an Africa aggregation), but it is not entirely clear from published documentation if modeling is done at the country or region level.

These models develop projections for the same set of supply and demand components as the FTP model, but they generally use more elaborate specifications for production and consumption functions. Parameters for equations are sourced from the literature or estimated econometrically using historical data. The models also incorporate prices and in two cases (IMPACT and HIS-GI) have prices bring about equilibrium in national, regional, and global commodity markets. However, even though they incorporate prices, all of the models are partial equilibrium models, because they only model the agricultural sector and not the economy as a whole. This means that developments in the agricultural sector do not influence the overall level of activity and income in the economy as a whole. The implications of this approach are discussed further below.

Published documentation for the IMPACT and FSA models give details on the equations used to specify supply and demand for commodities, and these details are summarized here.[25]

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[24] For published documentation on the FSA model, see U.S. Department of Agriculture (2011); for the IMPACT model, Rosegrant et al (2008); for the IHS-GI model, Kruse (2010.)

COMMODITY SUPPLY

All three models (IMPACT, FSA, and IHS-GI) model the domestic supply of a food commodity as an area harvested function times a yield function.

Specifications for the area harvested function are:

FSA:

$$AR = a(AR_{t-1}, RPY_{t-1}, RNPY_{t-1}, Z)$$

where AR is area planted or harvested (not clear which one), RPY is yield times real price, RNPY is yield times real price for substitute commodity, and Z is a set of exogenous policies.

IMPACT:

$$AC_{ti} = \mu_i * (PS_{ti})^{\varepsilon i_i} * \prod_{i \neq j} (PS_{tj})^{\varepsilon ij} * (1 + gA_{ti}) - (\Delta AC_{ti} * WAT_{ti})$$

where AC is crop area, μ is an intercept term, PS is the "effective producer price", ε is the elasticity of area with respect to price, gA is an exogenous growth factor for crop area (capturing factors such as expansion through population pressure, contraction from soil degradation, and conversion of land to non-agricultural uses), ΔAC is crop area reduction due to water stress, and WAT is a water variable.

Specifications for the yield function are:

FSA:

$$YL = y(LB, FR, K, T)$$

where LB is rural labor (based on population projection and accounting for urbanization growth), FR is fertilizer use (extrapolation of historical growth data), K is an indicator of capital use (extrapolation of historical growth data), and T is an indicator of technology change.

IMPACT:

$$YC_{ti} = \tau_i * (PS_{ti})^{\omega i} * \prod_{i} (PF_{tk})^{\omega ik} * (1 + gCY_{ti}) - (\Delta YC_{ti} * WAT_{ti})$$

where YC is crop yield, τ is an intercept term, PS is the "effective producer price", PF is a factor input price (eg capital or labor), ω is the elasticity of yield with respect to crop or factor input

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25 Available documentation for the IHS-GI model does not supply these details.

price, gCY is an exogenous growth factor for crop yield (capturing factors such as productivity growth driven by technology improvements due to crop management research, conventional plant breeding, wide-crossing and hybridization breeding, biotechnology and transgenic breeding, private-sector agricultural research and development, and agricultural extension and education), ΔYC is crop yield reduction due to water stress, and WAT is a water variable.

Commodity Demand

Consumption by domestic consumers of a commodity is modeled very differently in the IMPACT and IHS-GI models as opposed to the FSA model. In the IMPACT and IHS-GI models, consumption demand is modeled quite similarly to the approach taken in the FTP model. In the FSA model, consumption is not modeled but is derived as a residual that equals total domestic supply of a commodity minus all other components of demand.[26] Because all three models apparently use FAO data on commodities, this consumption component includes both direct consumption of a commodity as well as that embodied in processed foods (as in the case of the FTP model), and the issue that this is an approximation to true commodity consumption by domestic consumers discussed in appendix C applies to these models as well.

FSA:

Consumption by domestic consumers is a residual.

IMPACT:

$$QF_{ti} = \alpha_i * (PD_{ti})^{\varepsilon_i} * \prod_{i \neq j} (PD_{tj})^{\varepsilon_{ij}} * (INC_{ti})^{\gamma_i} * POP_t$$

where i and j index food commodities and t indexes time, QF is per-capita food demand, α is an intercept term, PD is the “effective consumer price” of a commodity, ε_i is the own-price elasticity for commodity i, ε_{ij} is the cross-price elasticity between commodities i and j, INC is per-capita income, γ is the income elasticity of demand, and POP is total population of the country.

No distinction is made in the FSA, IMPACT, and IHS-GI models between rural and urban households.

Demand for feed is specified as:

FSA:

Exogenous (no details provided in published documentation.)

IMPACT:

[26] The FTP model derives net exports as a residual rather than consumption. See section below on achieving model closure for further discussion.

$$QL_{tb} = \beta_b * \sum_L (QS_{tL} * FR_{tbL}) * (PI_{tb})^{\theta b} * \prod_{o \neq b} (PI_{to})^{\theta ob} * (1 + FE_{tb})$$

where b and o index feed commodities, QL is demand for feed, QS is production of livestock product for animal type L, FR is the feed ratio, PI is the "effective intermediate feed price," θ is the price elasticity of feed demand, and FE is a feed efficiency improvement factor.

Demand for seed is specified as:

FSA:

Endogenous, based on harvested area and a constant seed/area ratio.

IMPACT:

Demand for seed is not explicitly discussed in published documentation. It apparently is implicitly a component of demand for other uses (see below.)

Demand for other uses:

FSA:

Exogenous (no details provided in published documentation.)

IMPACT:

$$QE_{ti} = QE_{t-1,i} * \left(\frac{QF_{ti} + QL_{ti}}{QF_{t-1.i} + QL_{t-1,i}} \right)$$

where QE is demand for other uses, QF is demand for food, and QL is demand for feed. QE is adjusted upwards by the growth rate of the sum of demand for food and demand for feed.

One component of demand that is not incorporated in the FTP model is demand for biofuels, which is incorporated in the IMPACT and IHS-GI models:[27]

IMPACT Specification:

$$QB_{ti} = f(GM_{ti}, EP_{ti}, PSE_{ti})$$

where QB is demand for biofuel feedstock, GM is government blending mandates, EP is energy price, and PSE is producer subsidy equivalents of both subsidies and trade measures. Note that

[27] It is not clear whether biofuel demand is incorporated in the FSA model, as nothing is stated about this in published documentation. It might be a component of other uses.

this is domestic demand for biofuels: net exports of food commodities in this model are determined as a residual (see below), and exports of biofuels are thus not modeled separately from total exports of a commodity.

Exports and imports are modeled separately in the FSA model. Exports exogenous and are based on population growth rate or extrapolation of historical trend. Imports are specified as:

$$CI = f(WPR, NWPR, FEX, PR, M)$$

where CI is commercial imports, WPR is the real world price for the commodity (USDA baseline projection), NWPR is the real world price for a substitute commodity (USDA baseline projection), FEX is real foreign exchange availability, PR is domestic production of the commodity, and M is import restriction policies.

In the IMPACT and IHS-GI models, for a given level of the global price of a food commodity, net exports of a commodity for a country are determined as the difference between domestic supply and domestic demand. Net exports are then summed up across countries, and if they do not sum up to zero, the global price adjusts until they do. At the individual country level, some countries will be net exporters of a commodity and some will be net importers, but model equilibrium requires that the level of global net exports be zero.

Achieving Model Closure

The FSA and FTP models achieve closure by making a variable a residual The FSA model makes consumption by domestic users a residual, and the FTP model makes net exports a residual. The IMPACT and IHS-GI models take a very different approach and achieve closure by endogenizing prices and solving for a price equilibrium in the global foodstuff market. The FSA and FTP markets thus force imbalance between *modeled* supply and demand components into the level of consumption and net exports, respectively. The IMPACT and HIS-GI models force imbalance between total supply and demand at the global level to impact the global market price of a commodity, change in the global price then affects supply and demand components and the regional or country level, and price adjustment continues until total supply and demand are equal and net exports of a commodity summed across countries equals zero.[28]

Partial versus General Equilibrium Models

As noted at the beginning of this appendix, all currently-available models of food commodity supply and demand are partial equilibrium models, because they only model the agricultural sector and not the economy as a whole. This means that developments in the agricultural sector do not influence the overall level of activity and income in the economy. This approach is plausible for countries whose agricultural sectors are relatively small compared to the overall economy. However, in low-income countries such as those of East Africa, the agricultural sector

[28] In the IMPACT and IHS-GI models, domestic prices are related to world market prices through a set of straightforward structural equations.

accounts for a substantial share of economic activity, typically between 20-30% of total value added and in some cases even more. Neglecting feedback between agricultural performance and the overall economy in these cases is potentially problematic, because a significant improvement or deterioration in agricultural performance could have a significant impact on macroeconomic outcomes.

In a full-blown general equilibrium approach to food commodity projection, commodity production outcomes would affect the level of value added in the agricultural sector, this would affect outcomes in other parts of the economy through intersectoral linkages, and these changes would feed back to the agricultural sector. Such a model does not currently exist, and constructing one would require a major effort. It might be possible to develop a simple approach that could be incorporated into the FTP model by making the real GDP growth rate endogenous and have it respond to food commodity production through a simplified, reduced-form type relationship.[29]

[29] Meijerink and Roza (2007) review evidence on linkages between the agricultural and non-agricultural economies in developing countries, including estimated values for multiplier impacts of growth in the agricultural sector on the economy as a whole (pp.14-18.) Although these multipliers have been thought to be low in sub-Saharan Africa, recent evidence suggests that this may not be the case.

Appendix B. Land Availability in Sub-Saharan African Countries

In order to assess whether a country is constrained by availability of land for agricultural purposes, it is necessary to develop measures of the total supply of land that could potentially be used for agriculture and the amount that is currently in use. Land currently in use to produce crops or serve as pastures is termed "arable land," and data on arable land is collected and published on a regular basis.[30] Data on the supply of land that potentially could be used for agriculture is not regularly collected. Special studies have been conducted to estimate potential arable land, and the FAO publishes estimates for 1994 for all countries of the world in its TERRASAT database.[31] Table B1 shows data for potential arable land, equivalent potential arable land, and actual arable land for all sub-Saharan countries. East African countries are identified by yellow highlight.

Potential arable land is all land that could be used for some agricultural purpose, equivalent potential arable land adjusts potential arable land for its quality (taking into account that some types of land are better suited for agricultural use than others), and actual arable land is land that is in use for agricultural purposes. The table also gives the ratios of actual arable land to potential and equivalent potential arable land. It is possible for actual arable land to exceed potential arable land because of irrigation and other techniques that make land that could not otherwise be used for agriculture available. Desert countries will usually have ratios above unity due to irrigation.

Many sub-Saharan countries are not constrained by land availability at the national level.[32] For sub-Saharan Africa as a whole, the ratios of arable land to potential and equivalent potential arable land are 14% and 21% respectively, which indicates a very high level of unused land supply. Some countries have ratios close to or over 100% and are clearly constrained, including countries with large deserts (Eritrea, Somalia) and high population density (Burundi, Lesotho,

[30] FAO publishes time series by country on arable land in total and broken down by components (cropland, pasture land.) This data is re-published in other databases, such as World Development Indicators.

[31] See Food and Agricultural Organization of the United Nations, Land and Water Development Division (2000a) and (2000b).

[32] This analysis is at the national level. For countries with low ratios, it is possible that particular regions or areas are constrained by available land, and expansion of agricultural activities might require internal migration to areas where land is available.

Rwanda). Other countries have arable-equivalent potential ratios between 60-90% and may be land constrained in some areas (Niger, Nigeria, South Africa, Togo, Uganda.) For East African countries, only Burundi, Rwanda and Uganda appear to have any potential issue with constraints on land supply.

Table B1

	Potential arable land (A)	Equivalent potential arable land (B)	Actual arable land (C)	(C)/(A)	(C)/(B)
		Thousand hectares			
Angola	88,105	53,914	3500	4%	6%
Benin	9,753	7,862	1880	19%	24%
Botswana	9,173	5,045	420	5%	8%
Burkina Faso	20,341	15,245	3565	18%	23%
Burundi	1,414	851	1180	83%	139%
Cameroon	35,910	25,706	7040	20%	27%
CAR	47,887	35,250	2020	4%	6%
Chad	33,051	24,118	3256	10%	14%
Congo D. R.	167,831	109,645	7900	5%	7%
Congo Republic.	22,995	15,626	170	1%	1%
Cote d'Ivoire	26,226	18,700	3710	14%	20%
Djibouti	0	0	0	0%	0%
Equatorial Guinea	1,646	1,161	230	14%	20%
Eritrea	590	262	519	88%	198%
Ethiopia	42,945	29,220	11012	26%	38%
Gabon	17,873	13,212	460	3%	3%
Gambia	785	600	172	22%	29%
Ghana	18,321	13,233	4320	24%	33%
Guinea	13,217	8,912	730	6%	8%
Guinea-Buissau	2,306	1,500	340	15%	23%
Kenya	15,845	9,806	4520	29%	46%
Lesotho	362	196	320	88%	163%
Liberia	6,294	4,307	375	6%	9%
Madagascar	35,602	22,793	3105	9%	14%
Malawi	6,771	5,099	1700	25%	33%
Mali	26,513	17,383	2503	9%	14%
Mauritania	1,381	715	208	15%	29%
Mozambique	63,544	44,002	3180	5%	7%
Namibia	11,889	6,539	662	6%	10%
Niger	10,278	5,450	3605	35%	66%
Nigeria	66,230	47,813	32700	49%	68%
Rwanda	746	474	1170	157%	247%
Senegal	13,270	9,037	2350	18%	26%
Sierra Leone	3,955	2,788	540	14%	19%
Somalia	2,381	1,016	1020	43%	100%
South Africa	28,097	17,898	13179	47%	74%
Sudan	86,728	62,945	12975	15%	21%
Swaziland	805	471	191	24%	41%

	Potential arable land (A)	Equivalent potential arable land (B)	Actual arable land (C)	(C)/(A)	(C)/(B)
Tanzania	67,285	45,911	3500	5%	8%
Togo	4,291	3,044	2430	57%	80%
Uganda	14,169	9,784	6800	48%	70%
Zambia	58,471	40,559	5273	9%	13%
Zimbabwe	24,575	14,251	2878	12%	20%
Total	**1,109,851**	**752,344**	**157608**	**14%**	**21%**

Source: Food and Agricultural Organization of the United Nations, Land and Water Development Division (2000b). Terrasat Database : *http://www.fao.org/ag/agl/agll/terrastat/#terrastatdb*

Appendix C. Food Commodity Consumption by Domestic Consumers in the FAO Data

The use of a commodity for consumption by final domestic consumers is calculated in the FAO data as a residual that is equal to total supply minus all components of demand other than consumption. The FAO residual does include consumption by all relevant final-user institutions, including households, businesses (e.g. company cafeterias), and the public sector (e.g. the military, government cafeterias.) However, the residual is only an approximation to the true domestic consumption of a commodity. True consumption should include consumption of all "primary commodities" that have been subject to no significant processing and all "processed commodities" that are embodied in processed foods. For example, a household might purchase wheat grain in order to make its own bread, and it might also purchase bread from stores that contains wheat. The residual should include both the wheat directly purchased by the household, and the wheat embodied in the bread that is purchased by the household. The problem arises with imports and exports of processed foods, which in this case would be imported bread purchased in stores by the household, and exports of bread made using wheat produced in this country.[33]

Let components of a commodity's supply and demand components be defined as:

DD is domestic production that is directly purchased by domestic final consumers;

DPC is domestic production that is used by domestic food processing industries, and embodied in products sold to domestic final consumers;

DPX is domestic production that is used by domestic food processing industries, and embodied in exports of processed foods;

DO is domestic production used for non-consumption and non-processing purposes (feed, seed, other uses, change in stocks);

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[33] See FAO's document: http://www.fao.org/fileadmin/templates/ess/documents/methodology/totdoc.pdf for a discussion of extraction rates and conversion factors for turning raw agricultural commodities into processed foods and how these rates have changed from the 1960s to the 1990s.

MD is imports directly purchased by domestic final consumers or used by domestic food processing industries and embodied in products sold to domestic final consumers;

MP is quantity of the commodity embodied in imports of processed foods that are sold to domestic final consumers;

MO is imports used for non-consumption and non-processing purposes (feed, seed, other uses, change in stocks);

XD is exports of the commodity.

The true domestic consumption of a commodity is:

$$C = DD + DP + MD + MP$$

There are two sources of error in the FAO residual. First, imports recorded by the FAO (and national statistical authorities) equal (MD+MO) and do not include the quantity of the commodity that is embodied in imported processed foods, MP. Second, exports recorded by the FAO (and national statistical authorities) include only XD, and do not include the quantity of the domestically-produced commodity that is embodied in exported processed foods, DPX. The FAO consumption residual equals domestic production minus recorded imports and recorded exports and is therefore equal to:

$$C^* = (DD+DPC+DPX+DO+XD) + (MD+MO) - XD - (DO + MO),$$

or:

$$C^* = DD + DPC + MD + DPX$$

The ratio of the true level of consumption to the residual is:

$$C - C^* = MP - DPX,$$

or:

$$(C - C^*)/C = (MP - DPX)/C$$

The degree to which the residual understates true consumption depends on the share of the quantity of the commodity embodied in imports and exports of processed foods, with the two sources of error offsetting each another. As a country's income level grows, the demand for imported processed foods embodying a commodity may rise faster than total demand for the commodity, in which case the degree of understatement rises. However, this is offset to the degree that exports of processed foods embodying the commodity rises faster than total domestic demand for the commodity. We have not as of yet been able to identify any study that evaluates this issue empirically.

Appendix D. Demand for Food Commodities by Domestic Consumers

TECHNICAL APPROACH TO PROJECTING DEMAND BY DOMESTIC CONSUMERS

The basic approach to projecting demand by domestic consumers in this model is to project real income growth rates, convert these into real household consumption expenditure growth rates, and then multiply these growth rates by an expenditure elasticity of demand for a food commodity that captures how demand for the commodity changes as real household expenditures grow (or fall.) As will be discussed further below, the model projects household consumption expenditures rather than income, because elasticities of demand for food commodities for developing countries are often estimated using household expenditures as a proxy for household income.

Projections of per capita real income for rural and urban households are developed according to the following formulas:

(1) $y_R = Y_R/P_R$

and

(2) $y_U = Y_U/P_U$,

where y_R and y_U are per capita real rural and urban income, Y_R and Y_U is total real income for rural and urban households respectively, and P_R and P_U are rural and urban population. Urban population P_U is determined by multiplying total population P by the urbanization rate (urban population as a percentage of total population), and rural population P_R equals the residual $P\text{-}P_U$. A forecast of total population during 2011-2020 is obtained from the United Nations or national sources. Historical data on the degree of urbanization is obtained from the World Development Indicators database and projected into the period 2010-2020 using simple extrapolative techniques.

Y_R and Y_U are determined by the following formulas:

(3) $Y_R = r*GDP$

and

(4) $Y_U = [1-r]*GDP$,

where r is the rural share of GDP. Real GDP is projected for 2011-2020 using IMF growth rate forecasts. A proxy for historical values of the rural share of GDP, r, is the ratio of agricultural value added to total value added; this ratio is projected into 2010-2020 using an average annual growth rate derived from historical values.[34] The model user is free to change assumptions on the projected real GDP growth rate, the population growth rate, the urbanization rate u, and the rural share of GDP, r.

Growth in the consumption of a commodity by rural and urban households is calculated using the following formulas:

(5) $g(C_i^R)= \varepsilon_i^R*c*g(y_R)$

and

(6) $g(C_i^U)= \varepsilon_i^U*c*g(y_U)$,

where C_i^R and C_i^U are consumption of commodity i by rural and urban households respectively, ε_i^R and ε_i^U are expenditure elasticities of demand for commodity i by rural and urban households, y_R and y_U are real rural and urban household final consumption expenditures respectively, c is a coefficient that converts real income growth into real household expenditures growth, and g(x) is the percentage growth rate of variable x. A value of 0.69 is used for the parameter c, whose derivation is described in more detail below.

The value of the FAO consumption residual for the last year in which historical data is available is divided into rural and urban consumption using data on relative shares from recent household budget surveys for Tanzania and Uganda. These levels are then projected forward using equations (5) and (6). Values for rural and urban expenditure elasticities of demand for a commodity have been determined through an extensive review of available literature discussed below, as well as new estimates of these elasticities presented in appendix F. Issues involved in identifying values for expenditure elasticities of demand, which are closely related to income elasticities of demand, are now discussed in detail.

INCOME ELASTICITIES OF DEMAND: OVERVIEW

How demand for food changes with the level of income has been an important area of research in applied economics since the work of the German statistician Ernst Engel in the 1850s. A general

[34] The value added ratio is a proxy for the true level of r because rural households have non-agricultural sources of income, and urban households have agricultural sources of income. We assume that agricultural-source income is the dominant component of rural household income, and non-agricultural-source income of urban income.

finding of this research is that total food expenditures have an income elasticity that is less than one, which means that an increase in real income of 1% leads to an increase in real food expenditures of less than 1%. Specific food commodities can be classed as inferior, necessity, or luxury goods, which by definition have an income elasticity of demand that is negative, between zero and one, and above one respectively. For high-income countries, a classic inferior food commodity is potatoes, whose demand in real terms falls as income rises; a classic necessity commodity is fresh vegetables, and a classic luxury is fine wine. The values of income elasticities for food commodities will also generally change with income. Generally speaking, a poor country will have elasticities for foodstuffs that are significantly higher than those of a rich country.

Income elasticities of demand can be estimated using time series data (observations on real income and the quantity of a food commodity consumed for a specific household or country at different points in time), cross-sectional data (observations on real income and the quantity of a food commodity consumed across different households or countries at the same point in time), or panel data that combine time series and cross-sections. Each approach has been used in research over the past several decades to estimate elasticities for food commodities in developed and developing countries, and each involves special challenges and considerations. A full review of this literature is beyond the scope of this study, but we attempt to summarize here the key issues involved in estimating these elasticities.

Household budget surveys provide data at a particular point in time on the levels of consumption of food commodities and other goods and services for a sample of households in a country. Statistical (econometric) techniques can be used to estimate the relationship between household income and consumption of a particular commodity by taking advantage of the variations in consumption and income present in the sample of households. Household surveys have become increasingly widely available for developing countries over the last three decades , and a literature that estimates income and price elasticities of demand for various goods and services has emerged.

Estimating income elasticities using household budget survey data faces several challenges. First, estimation should be carried out in the context of a theoretical demand specification that covers all goods and services. Best practices regarding demand system specification have been well-established. Second, there is variation in the price that is paid for a good by different households at the same point in time, and this should be controlled for. The quality of the good may vary, and this is not usually recorded by the survey. If the quality of a good changes systematically with expenditure level, this will bias estimates of the expenditure elasticity of demand. In addition to unobserved quality variation, prices may differ across geographical regions due to differences in transport cost, levels of market competition, and other factors. Third, estimation should control for household characteristics that might influence demand for particular goods and services.

Fourth, household budget surveys often do not provide values for total household income. In this situation, total household expenditure on goods and services is used as a proxy for income.[35]

Recent research has used sophisticated techniques to control for quality variation and estimate income and price elasticities of demand using household budget survey data.[36] However, these estimates are often for aggregated groups of food commodities (e.g. starches, vegetables and fruits, meat, bread, dairy) or for food as an aggregate. It has been difficult to find research based on household budget survey data that provide elasticity values for the specific food commodities of the FTP model.

Income elasticities of demand have also been estimated for food commodities using data on consumption and income at the aggregate national level. Time series analysis can be carried out on national-level consumption and income data for one country. This approach could be applied to the FAO data on food consumption of the commodities in the FTP model.[37] Another approach is to use data on consumption of various goods and services and income at the national level and estimate elasticities on a cross section of countries at a given point in time or across countries and years (panel estimation.)[38]

It should also be noted that although projection and forecasting models keep elasticity values constant over time, the empirical evidence suggests that elasticity values generally change over time with real income.[39] Yu et al (2004) review empirical evidence on this and show that the demand systems that are used by almost all projection models do not permit change in income elasticity values. As a result, these demand systems tend to over-estimate future food demand and

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[35] Bouis (1994) provides an interesting critique of income elasticity estimates using household food expenditure survey data and suggests that these surveys do not adequately account for food transfers from high to low income groups. He notes that this problem should not be present in surveys that record food intake directly, which has become standard practice for household surveys in developing countries.

[36] See Dimov el al (2011) for a cutting-edge study of estimation of income and price elasticities of demand using household budget survey data for Bulgaria. Weliwita et al (2003) estimate expenditure and price elasticities of demand using household budget survey data for Tanzania in 1991-92: they aggregated food commodities into broad groups, and estimated expenditure elasticities vary widely and sometimes have unexpected signs (for example, meat has a negative elasticity value.) Ecker and Qaim (2010) use 2004-2005 household budget data for Malawi to estimate elasticity values for specific food commodities that are comparable to those of the FTP model.

[37] A good example of how such time series research has been done for an east African country is Nzuma and Sarker (2008), who estimate income and price elasticities of demand for cereal crops in Kenya using FAO data for the period 1963-2005. Malik and Aziz (2006) use time series data for Pakistan during 1950-2003 to estimate income and price elasticities for major food commodity aggregates.

[38] Wu (2004) uses data from the International Comparison Project for 1970-1995 to estimate elasticities for aggregate food commodity groups for regional country groups and groups of countries at various income levels. Selvananthan and Selvanathan (2006) estimate income elasticities for broad consumption groups (including food) using an unbalanced panel data of developed and developing countries during 1961-1997.

[39] See, for example, Wu (2004) for empirical analysis of food demand over 1970-1995 that shows that the income elasticity of demand for food commodity aggregates tends to fall with real income growth.

thus future production and import requirements. The projection horizon that they use to demonstrate over-prediction is 25 years. The FTP model has a projection horizon of 10 years, so the degree of over-prediction in FTP projections will be smaller.

INCOME ELASTICITES VERSUS EXPENDITURE ELASTICITIES

Elasticities that are used in analysis of food commodity demand in developing countries, including those used in the FTP model, are usually estimated by relating the level of food commodity consumption to total household expenditures, not income.[40] These elasticities are thus expenditure elasticities of demand, not income elasticities of demand. It is necessary to make these elasticities consistent with the real GDP growth projections, as projections of real household consumption at the national level are generally not available. In order to do this, the historical relationship between growth in real per capita household consumption expenditures, h, and real per capita income, y, is estimated econometrically using the equation:

$$(5) \qquad g(h) = a + c*g(y)$$

This could be done on a country-by-country basis, so that estimates of c are specific to each African country. However, data on h are available for fewer sub-Saharan African countries than data on y, and the quality of available data for h seems lower than for overall income y. We thus estimate an unbalanced OLS panel regression using data on h and y for 39 sub-Saharan African countries for the period 1961-2011. Regression results below show that growth in real household consumption expenditures was roughly 70% that of real GDP on average for these countries in this time period. We use the estimate of 0.69 as a value for the parameter c in equations (5) and (6).

Table D1

Consumption-Income Growth Rate Regression

Variable	Coefficient	Standard error	T-statistic
Constant	-0.00	0.00	-0.84
Growth in per capita real GDP	0.69	0.04	16.39
R^2	0.17		
R^2adj	0.17		
F statistic	268.55		
Prob(F-statistic)	0.00		
Total pooled (unbalanced) observations: 1,282			
Number of included cross-sections (countries): 39			

[40] Surveys often do not permit calculating total household income, and total expenditure is used as a proxy for total income.

EXPENDITURE ELASTICITIES OF DEMAND FOR THE FTP MODEL

Table D2 below summarizes expenditure elasticities of demand for specific food commodities or food commodity groups that have been estimated for sub-Saharan countries in studies done in academia, think tanks, and governments.[41] Results obtained in appendix F of this report are also included. Almost all of these studies use cross-section household survey data to estimate elasticities, so that the elasticity results from how consumption changes with total expenditures across households at a given point in time. One study uses time series data for Kenya to estimate elasticities for four cereal crops. To the extent to which they can be compared, elasticity values are generally fairly consistent across studies. Values are generally high, usually close to unity, which is not surprising given the low levels of income in sub-Saharan African countries.

In order to obtain baseline elasticity values for the FTP model, we take the average of the elasticity values from individual studies that provide estimates of elasticities for rural and urban households separately. In cases where food commodities are grouped together, the group elasticity value is used. For example, the expenditure elasticity for maize for rural households is calculated as the average of 1.08, 0.948, 0.909, and 1.047.[42] For some food commodities, few or no elasticities specific to that commodity (as opposed to a group that the commodity is in) are available. This may be a significant issue in the case of commodities like millet, sorghum, and cassava, which are believed to be goods whose demand rises significantly less with income than many other food commodities.

[41] We use studies that could be found for all sub-Saharan African countries as so few are available.

[42] We do not incorporate into the average estimates of the other studies for various reasons. Weliwita et al (2003) do not provide separate estimates for urban and rural households; their estimates are, however, consistent with those of the studies that are used. Regmi et al (2001) do not provide separate estimates for urban and rural households, and their estimates are not derived from household survey data but on from a cross section of country-level data that includes national-average food consumption levels, prices, and incomes. The elasticity values estimated in this study are somewhat lower than those of the studies based on household survey data. The estimates of Nzuma and Sarker (2008) study do not provide separate estimates for urban and rural households; for the four cereal commodities covered in this study, their elasticity values are fairly close to unity.

Table D2

Expenditure Elasticities of Demand for Food Commodities in Sub-Saharan African Counties

Study	Tafere et al (2010)		Ecker and Qaim (2010)		Appendix E			
Country(ies)	Ethiopia		Malawi		Uganda (table E4)		Tanzania (table E5)	
Data type	Survey: household cross-section		Survey: household cross-section		Survey: household cross-section		Survey: household cross-section	
Time period	2004/05		2004/05					
Parameter estimated	AIDS expenditure elasticity		AIDS expenditure elasticity		AIDS expenditure elasticity			
	Rural households	Urban households	Rural households	Urban households	Rural households	Urban households	Rural households	Urban households
Maize	1.08	1.14	0.948	0.628	0.909 (l)	0.870 (l)	1.047 (l)	0.884 (l)
Rice			0.892	0.904				
Wheat	0.42	0.41	1.326 (a)	1.382 (a)				
Sorghum	1.00	-0.81						
Millet								
Cereals, Other	1.08 (q)	1.14 (q)						
Beans	1.13	0.87	1.365	0.197				
Peas			0.704	0.158				
Soybean								
Cassava	0.18 (r)	0.59 (r)	-0.665	0.076				
Plantain								
Potato			0.712	1.004				
SweetPotato								
Yams								
Other Roots								
Banana	0.95 (d)	0.87 (d)	0.563	0.278	0.986 (d)	0.924 (d)	0.548 (d)	0.946 (d)
Groundnut	0.96 (s)	2.10 (s)	0.744	0.413	0.814 (h)	0.819 (h)	0.663 (h)	0.805 (h)
Sesame Seed			1.069 (h)	1.382 (h)				
Palm Oil								
Bovine Meat	1.22 (t)	1.23 (t)	0.865 (i)	1.377 (i)	1.183 (m)	1.214 (m)	1.266 (m)	1.221 (m)
Mutton or Goat								
Pig Meat			0.862 (j)	1.501 (j)				
Poultry Meat								
Milk			0.870 (k)	1.514 (k)	1.286 (n)	1.288 (n)	1.159 (n)	1.424 (n)

Table D2 (continued)

Expenditure Elasticities of Demand for Food Commodities in Sub-Saharan African Counties

Study	Weliwita et al (2003)	Regmi et al (2001)		Nzuma-Sarker (2008)	
Country(ies)	Tanzania	146-country cross section		Kenya	
Data type	Survey: household cross-section	International Comparison Project database		Time series	
Time period	1991/92	2005 (update of original work in 2001)		1963-2005	
Parameter estimated	AIDS expenditure elasticity	Income elasticity of demand		AIDS expenditure elasticity	
		East Africa country average	ECOWAS country average	Short-run	Long-run
Maize	0.988			0.828	0.928
Rice	0.951			0.643	0.920
Wheat		0.607 (o)	0.580 (o)	0.568	0.618
Sorghum	1.053 (a)			0.657	0.766
Millet					
Cereals, Other					
Beans					
Peas	1.012 (b)				
Soybean					
Cassava					
Plantain					
Potato	1.039 (c)				
SweetPotato		0.672 (p)	0.655 (p)		
Yams					
Other Roots					
Banana	1.079 (d)				
Groundnut					
Sesame Seed					
Palm Oil	0.915 (e)	0.617 (h)	0.592 (h)		
Bovine Meat					
Mutton or Goat	0.823 (f)	0.808 (f)	0.797 (f)		
Pig Meat					
Poultry Meat					
Milk	0.869 (g)	0.836 (g)	0.825 (g)		

Notes: (a) : "other cereals" (not including maize and rice); (b) : "pulses"; (c) : "starches"; (d) : "fruits and vegetables"; (e) : "edible oils"; (f) : "meats"; (g) : "dairy"; (h) : "fat and oil"; (i) : "red meat"; (j) : "white meat"; (k) : "milk and dairy products"; (l) : "starches"; (m) : "meat and fish (incl.eggs)"; (n) : "drinks" (incl. milk, coffee, tea, soda, beer, other alcoholic drinks, other drinks); (o) : "cereals, bread"; (p) : "fruits and vegetables, including roots and tubers"; (q) : teff; (r) : "root crops"; (s) : "oil seeds"; (t) : "animal products" (incl. meats, fish, milk and milk products, eggs).

ARE THESE EXPENDITURE ELASTICITY VALUES “TOO HIGH”?

The consumption growth rates of the FTP’s baseline projections as shown in tables 3 and 4 are quite high. This is due to both a doubling in the growth rate of per-capita real income and the high elasticity values derived from table D1. It is important to note that these expenditure elasticities of demand were obtained from cross-sectional household survey data, which provides insight into how demand changes across households at different expenditure levels at a given point in time. They are not necessarily consistent with the behavior of the FAO time series for consumption at the national level.

Table D3 presents results from evaluating the historical relationship between the FAO consumption series and real per-capita income directly through regression analysis. Ideally, a demand system such as the Almost Ideal Demand system would be used, and the influences of both prices and income estimated. Table D2 gives results from estimating a much simpler specification for 18 crop commodities in which the log of per-capita consumption of a particular commodity is regressed on the log of per-capita real income in a panel of sub-Saharan African countries for the period 1961-2007.[43] Elasticity values are generally much smaller than those estimated in household cross sections, suggesting that the behavior of the FAO series may not be consistent with household cross-section elasticities. Further investigation of this issue is beyond the scope of this study. The next section shows that such an inconsistency has been identified for the important historical example of Britain during the Industrial Revolution.

[43] Producer price series are available from the FAO for many country-commodities for the period 1991-2007, but consumer price series are not available.

Table D3

Panel Regressions: Log of FAO Per-Capita Consumption on Log of Per-Capita Real GDP Index

Crop	Year Fixed Effects	Coefficient on log of real per capita GDP index	Robust standard error	Observations	R-squared
Bananas	No	0.309***	(0.0459)	1,228	0.936
	Yes	0.279***	(0.0457)	1,228	0.938
Beans	No	0.481***	(0.0659)	869	0.931
	Yes	0.509***	(0.0768)	869	0.936
Cassava	No	-0.210***	(0.0705)	1,237	0.868
	Yes	-0.335***	(0.0712)	1,237	0.879
Cereals Other	No	-0.808***	(0.154)	957	0.792
	Yes	-0.536***	(0.156)	957	0.812
Groundnuts (Shelled Eq)	No	0.154***	(0.0548)	1,291	0.788
	Yes	0.081	(0.0573)	1,291	0.808
Maize	No	0.007	(0.0354)	1,537	0.930
	Yes	-0.101**	(0.0398)	1,537	0.935
Millet	No	-0.195*	(0.107)	1,205	0.891
	Yes	-0.015	(0.0981)	1,205	0.919
Palm Oil	No	0.098	(0.0690)	1,018	0.761
	Yes	0.107*	(0.0639)	1,018	0.779
Peas	No	-0.404***	(0.144)	466	0.852
	Yes	-0.346**	(0.161)	466	0.881
Plantains	No	0.066***	(0.0190)	578	0.981
	Yes	0.046**	(0.0206)	578	0.983
Potatoes	No	0.778***	(0.0578)	1,353	0.886
	Yes	0.688***	(0.0490)	1,353	0.898
Rice (Milled Equivalent)	No	0.614***	(0.0595)	1,542	0.879
	Yes	0.485***	(0.0536)	1,542	0.929
Sesameseed	No	-0.888***	(0.175)	574	0.662
	Yes	-0.944***	(0.170)	574	0.681
Sorghum	No	-0.324***	(0.0437)	1,327	0.897
	Yes	-0.113***	(0.0398)	1,327	0.922
Soyabeans	No	-0.049	(0.0652)	467	0.720
	Yes	0.203***	(0.0740)	467	0.788
Sweet Potatoes	No	-0.102*	(0.0560)	1,223	0.888
	Yes	-0.199***	(0.0530)	1,223	0.905
Wheat	No	0.232***	(0.0712)	1,600	0.758
	Yes	0.004	(0.0576)	1,600	0.844
Yams	No	-0.038	(0.0390)	807	0.962
	Yes	-0.014	(0.0360)	807	0.965

FOOD COMMODITY QUANTITIES VERSUS EXPENDITURES: IMPLICATIONS FOR PROJECTIONS

An interesting puzzle in the development of food commodity demand over the course of the Industrial Revolution may be relevant to projections of food demand in developing countries today. Clark et al (1995) show that the strong real income growth in Britain during 1770-1850 in combination with even a modest income elasticity of demand for food implies that demand for food commodities should have grown strongly. However, actual consumption of food commodities, which they measure as food supply (production plus net imports), did not grow or even declined over this period. This has an obvious implication for models of food commodities that use income growth and elasticities of demand to make consumption projections: the British experience suggests that this approach could over-estimate food commodity demand in real terms, particularly at long projection horizons.

Clark et al conclude that “the puzzle apparently does not stem from errors in estimating foodstuff supplies. Rather, a variety of forces break the tight links usually assumed between foodstuff supplies, final food consumption, and income. These include a sharp decline in food demand elasticity with income as income increases, declines in food demand as a result of urbanization and occupational change, and the often neglected difference between final foods and the agricultural inputs (here ‘foodstuffs’) that go into them. We find in these effects at least a partial resolution of the food puzzle, both for Britain in the period 1770-1850 and for other settings.” (p.215) The “difference between final foods and the agricultural inputs that go into them” has to do with the rise in demand for processed foods: as income grows, demand for a particular food commodity may stay flat in quantitative terms (tons consumed), but that quantity is subject to increasing levels of being processed and thus is producing higher levels of value added in the national accounts. Clark et al find that a significant part of the divergence between projected and actual food consumption can be explained by this rise in demand for processed foods and decline in the elasticity of demand for food with income, but that rise in the level of urbanization explains almost none of it. They also find that change in age and income distributions cannot explain any of the divergence. Finally, they suggest that another factor contributing to the divergence may be the large fall in the relative price of keeping warm in the British climate, which is captured by the relative price of coal and clothing (they cannot however quantify this impact.)

Demand for processed foods in developing countries is likely to increase with income. An assessment of the implications of this for food commodity projection models, and the use of the projections that they generate, would be worthwhile. Existing models project the FAO consumption residual and do not incorporate a food processing industry. One implication is that consumer welfare associated with food commodity consumption may be rising even if consumption of food commodities in quantitative terms does not change.

Another hypothesis that can help explain this puzzle is provided in Banjerjee and Duflo (2011), which argues that declines in caloric demand in India was the result of mechanization of agriculture. This transition from labor intensive to capital intensive agriculture resulted in a decline in human effort, and thus of caloric need. A similar argument might also be made for expansion of the rural road infrastructure and improvements in milling techniques.

Appendix E: Macroeconomic and Food Commodity Data for Southern Sudan

Data on macroeconomic and food variables for Southern Sudan are not yet available in international databases and must be gathered from special reports and the first Southern Sudan statistical yearbook.

POPULATION AND INCOME DATA

Although no data is yet reported for Southern Sudan in databases such as World Development Indicators, it is possible to develop data on population and income in recent years. A value for total population in 2008 is available from the census conducted by Sudan in that year.[44] Population values for 2010 and 2011 have been estimated by the FAO.[45] A population value for 2009 is calculated as the average of the 2008 and 2010 values. An urbanization rate for 2009 is provided in the CIA World Fact Book. GDP and household final consumption in current prices has been estimated for 2008-2010 by the National Bureau of Statistics. Finally, average total household expenditures for rural and urban households in 2009 are available.[46]

These data are incomplete but can be used to establish values in 2009 for key population and income variables that can serve as a starting point for making projections.

[44] Results from the Sudanese 2008 census have been disputed.

[45] See FAO (2011), table 2 and p.5.

[46] These values are estimated using national baseline household survey data. See Southern Sudan Centre for Census Statistics and Evaluation (2010a).

ESTIMATE OF FOOD COMMODITY CONSUMPTION IN SOUTHERN SUDAN FOR 2009

A national baseline household survey (NBHS) was conducted in Southern Sudan in April-May 2009 on a randomly-selected sample of 5,280 households.[47] This survey provides data on the daily food basket for the average person in this sample in terms of daily quantities consumed, and these quantities were converted into kilocalorie equivalents by the survey implementer.[48] We convert daily quantities consumed into annual quantities consumed at the national level using an estimated 2009 population value of 8.617 million people. The survey collected data on cereals, cassava, soyabeans, and groundnuts for unprocessed and processed (flour) consumption separately. In order to develop the aggregates presented in table 1 in the text, processed (flour) consumption is converted into grain-equivalent units using an appropriate conversion factor.[49] Milk products (butter, ghee, milk powder) are similarly converted into fresh milk equivalent units.

Table E1 gives NBHS data on consumption per person per year and kcal consumption per person per day by food commodity, and an estimate of total national consumption of each food commodity in metric tons. The average Southern Sudanese is estimated to have consumed 2,399 kilocalories (kcals) per person per day in 2009. As discussed in the main text, this may be the highest level of kcal consumption in the East Africa region and is consistent with FAO data on kcal consumption, which has Sudan at the highest level of kcal consumption in the East Africa region in 2006 and 2007.

However, a recent FAO/WFP assessment of food security in Southern Sudan published in January 2011 cites a much lower estimated level of cereal consumption than the estimates in table E1. Table E2 compares these two cereal consumption estimates: the FAO/WFP estimate is only 56-76% of the value directly derived from the 2009 NBHS data.[50] The reasons for this divergence are not clear; both estimates are apparently based on the same underlying data.[51] If

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[47] See Southern Sudan Centre for Census Statistics and Evaluation (2010a). Urban households were over-sampled to gain more precision on estimates for these households.

[48] See Southern Sudan Centre for Census Statistics and Evaluation (2010a), appendix A.

[49] Wheat also includes other products (bread, buns, biscuits) that are converted into grain-equivalent units.

[50] The range depends on whether flours are included in the NBHS-based estimate or not. It is not clear if the FAO/WFP estimate includes flour grain-equivalents. If it does, then the 56% value is applicable.

51 The FAO/WFP estimate is stated to be based on a 2009 NBHS value for cereals consumption per person per year of 108 kilograms. However, the data of table E1, which are taken directly from the report on the 2009 NBHS, show that 108 kilograms is far too low: sorghum consumption alone is 152 kilograms. FAO/WFP (2011) states that “Estimates of cereal per capita consumption are based on information provided by the 2009 National Baseline Household Survey (NBHS) at state level and adjusted by the Mission at county level to take into account differences between urban and rural areas and the relative importance of crops and livestock in local diets. Per capita food consumption rates by the 2009 NBHS are generally higher than those used in past CFSAMs. In addition, the Mission decided to augment 2009 cereal consumption figures by 5 percent to take into account that the NBHS may have somehow underestimated

the FAO/WFP cereal consumption estimate is more plausible than that of table E1, then the total kcal consumption level of table E1 is also significantly too high.

FOOD COMMODITY PRODUCTION AND PROJECTION METHODOLOGY

The only data that are available on production of food commodities in Southern Sudan are for aggregated cereals produced in the traditional sector. Table E3 presents data on area, net production, and yield for aggregated cereals, which are available for the period 2004-2010 (no data has been published for individual cereal crops.)[52] In order to develop projections for individual cereal crops, we first estimate 2010 production of individual cereals by applying the percentage share of each cereal in consumption in 2009 (from table E1.) We then assume a value for the yield of each cereal crop in 2010. Three different scenarios are considered: the average of 2009 yields in Southern Sudan's neighbors, the lowest 2009 yield value in Southern Sudan's neighbors, and the 2009 yield value for Sudan.[53] The implied values for area for aggregated cereals for these three scenarios are 1,022,568, 522,767, and 915,441 hectares respectively, which is 90%, 176%, and 101% of the value of estimated actual area in 2010 (see table E3.) The Sudan yield values thus best fit the empirical data that we have available to us, and we set these yields as baseline values for projections. No growth is evident in the historical data for 1990-2009 for these yields in Sudan, and the historical yield growth rates are all set at 0%. Finally, growth rates for area harvested must be set for each cereal crop. The average annual growth rate of area for aggregated cereals in Southern Sudan during 2004-2010 (table E3) was 5.3%. We assume that this growth rate will hold in future. As we have no way to determine a growth rate for cereal crops individually, we assume that this growth rate will apply to each cereal crop.[54]

Projections for seed use, feed use, processing, and other utilizations for each cereal crop are developed as for other countries using the historical relationships found in food balance sheet data for Sudan. Projections for consumption are also made according to the methodology used for the other countries. However, the consumption level for each cereal can be set at either the level of table E1 or 0.56 times this level to force total cereal consumption to equal the FAO/WFP estimate. Projected net exports are negative and very large under the consumption levels of table E1, and these projections do not seem realistic. The FAO/WFP cereal consumption estimate seems more plausible than the estimate of table E1 in light of the projection outcomes. It would be worthwhile to understand why these estimates are so different.

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food consumption because of two factors: 1) it was conducted in a year when cereal production was severely affected by drought and 2) it was conducted during the lean season period when overall food consumption usually decrease. Consequently, used consumption rates varied from 80 to 140 kg per capita per year." (p.16) This explanation does not explain the divergence, as it suggests that the Mission increased the 2009 NBHS consumption rates.

[52] Cereals include maize, millet, rice, sorghum, and wheat.

[53] Southern Sudan's neighbors include Sudan, Uganda, Ethiopia, and Kenya.

[54] Historical data on production and area for individual cereal crops in Southern Sudan probably exist but have not been published.

For non-cereal food commodities, the only data that is available is the consumption data of table E1. Without any data on the production side, in order to make projections, net exports must be assumed to equal zero, and production calculated as the residual. Although zero net exports may well be a plausible assumption for these commodities[55], this approach violates a core projection principle of this model and would make these projections inconsistent with all other projections. If one recent year of relevant production data becomes available, these projections can be generated.

Note that because no historical data is available for Southern Sudan for any individual food commodity, when Southern Sudan is included in a regional aggregation in the model, only projection data is displayed.

Table E1

South Sudan: Food Commodity Consumption by Households in 2009

	Total national consumption (metric tones)	Consumption per person per year (kilograms)	Kilocalories per person per day
Wheat[A]	19,179	2.2	23
Rice[A]	6,913	0.8	8
Maize[A]	293,913	34.1	301
Millet[A]	47,511	5.5	46
Sorghum[A]	1,308,398	151.8	1,362
Cassava[A]	324,254	37.6	144
Potatoes (Irish)	0	0.0	0
Sweet potatoes	2,665	0.3	1
Pumpkins	12,097	1.4	1
Groundnuts[A]	58,840	6.8	103
Beans	21,081	2.4	23
Peas	0	0.0	0
Soyabeans[A]	721	0.1	1
Fruits[B]	142,633	16.6	30
Vegetables[C]	41,793	4.9	4
Bovine meat	27,554	3.2	15
Sheep/goat meat	25,492	3.0	9
Pig meat	1,367	0.2	1
Poultry	9,678	1.1	6
Milk[D]	112,490	13.1	39
Other foodstuffs[E]	243,096	28.2	282
TOTAL			**2,399**

A: Includes flour (converted to grain equivalent.)
B: Local and cooking bananas, mangoes, pineapples, dates, and papayas. (Apples, oranges and avocadoes covered in survey but

[55] Historical data for Sudan during 1990-2007 shows that net exports were zero or negligible for non-cereal commodities.

had value of zero.)
C: Dry okra (alweka), onions, molokhia. (Carrots, cabbage, cucumber and tomatoes covered in survey but had value of zero.)
D: Fresh milk, and milk powder, animal and vegetable butter, and ghee (converted to fresh milk equivalent.)
E: Other flour, pasta products, breakfast cereals, infant food, fish (fresh and dried), eggs, cooking oil, sugar, sugar cane, honey, and thanieh halawa.

Table E2

South Sudan: Total Cereal Consumption Estimates

	Total national consumption (metric tones)	Consumption per person per year (kilograms)
Estimates for 2011 based on published HBS report for 2009:[A]		
-including flours	1,763,078	195
-excluding flours	1,289,802	141
Calculated by FAO/WFP mission for 2011:[B]	986,000	108
-as % of published HBS estimate:		
-including flours	56%	56%
-excluding flours	76%	76%

Cereals include maize, millet, sorghum, rice, and wheat.
A : Source: table 1. 2011 estimates are derived using 2009 values for daily kilograms of consumption and the 2011 population estimate given in FAO (2011).
B : Source: FAO (2011), p.16.

Table E3

South Sudan: Cereal Production in the Traditional Sector

	Area (hectares)	Net Production (tons)	Yield
2004	677,000	490,000	0.72
2005	751,000	689,000	0.92
2006	788,000	709,000	0.90
2007	705,000	711,000	1.01
2008	853,000	1,068,000	1.25
2009	852,000	541,000	0.63
2010	920,798	695,000	0.75

Source: 2004-2009: Statistical Yearbook for Southern Sudan 2010, table 135. 2010: FAO (2011), table 4.

Appendix F. Expenditure and Price Elasticities of Demand for Food Commodities: Estimates Using Household Survey Data

(The primary author of this appendix is Dr. Monnet Gbakou.)

We use household budget survey data for Uganda in 2005 and Tanzania in 2008 to estimate expenditure and price elasticities of demand in a cross-sectional setting for rural and urban households separately. Highly sophisticated econometric techniques are employed that use a theoretically appropriate demand specification (the Almost Ideal Demand system), controls for variation in price due to variation in quality of the foodstuff purchased, and controls for household characteristics that might influence demand for particular goods and services. [56] As in the case of other studies using cross-sectional household data, because many households do not report consuming one or more foodstuff, an approach must be developed to take into account the presence of many zero values in the dataset without resorting to discarding all households that have one or more zero values. The approach taken here is to aggregate food commodities into a small number of groups: table F1 below gives the groups and the specific food commodities that they aggregate together.[57] After dropping all missing values, 3,676 Ugandan households (2.609 rural and 1,067 urban households) and 1,663 Tanzanian households (720 rural and 943 urban households) were included in the estimation dataset. Table F2 provides some descriptive statistics on the households in each sample. Table F3 provides descriptive statistics on consumption of the five commodity groups. We use total household expenditure on goods and services as a proxy for income.

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[56] Details of the estimation procedure, which are extensive and highly technical, are available upon request. The approach is based on that of Dimov el al (2011).

[57] The starch group in particular aggregates together many commodities. This was unavoidable given the number of zero values in the datasets and the need to avoid dropping observations.

Tables F4 and F5 give price and expenditure elasticities of demand for Uganda and Tanzania households, respectively. Own-price elasticities are on the diagonal of the price elasticity matrix, and cross-price elasticities are off the diagonal. As one would expect *a priori* given these countries' levels of income, expenditure elasticity values are high and sometimes exceed unity.

Table F1

Food Commodity Groups Used for Elasticity Estimation

	Uganda	**Tanzania**
Starches	Matoke (four varieties); Sweet Potatoes (Fresh); Cassava (dry); Cassava (Fresh), Cassava (Dry/ Flour); Irish Potatoes; Rice; Maize (grains); Maize (cobs); Maize (flour); Bread, Millet; Sorghum; Beans fresh); Beans (dry); Peas	Rice (puddy), Rice (hushed), Maize (green, cob), Maize (grain), Maize(flour), Millet and Sorghum (grain), Millet and Sorghum (flour); wheat, barley grain and other cereals; bread; Buns, cakes and biscuits, Macaroni, Spaghetti; Other cereal products; Cassava fresh, Cassava dry/flour, Sweet potatoes, Yams/Cocoyams, Irish potatoes; cooking bananas, Plantain; Other starches, Peas, Beans, Lentils, Other pulses.
Meat-and-fish	Beef; Pork; Goat Meat; Other Meat; Chicken; Fresh Fish; Dry/ Smoked fish; Eggs	Goat meat; Beef including minced sausage; Pork including sausage and bacon; Chicken and other poultry; Wild birds and insects; Other domestic/wild meat products; Eggs; Fresh fish and seafood (including dagaa); Dried/salted/canned fish and seafood (including dagaa), Package fish
Fat-and-oil	Cooking oil; Ghee; Margarine; Butter; Ground nuts (in shell); Ground nuts (shelled); Ground nuts (pounded)	Groundnut in shell/shelled; Cashew, almonds, and other nuts; Seeds and products from nuts/seeds (excluding cooking oil); Cooking oil; Butter, margarine, Ghee and other fat products
Vegetable-and-fruit	Passion Fruits; Sweet Bananas; Mangoes; Oranges; Other Fruits; Onions; Tomatoes, Cabbages; Dodo; Other vegetables	Onions, tomatoes, carrots, and green pepper, other vlungo; Spinach, cabbage, and other green vegetables, Canned, dried, and wild vegetables; Ripe bananas, citrus fruits (oranges, lemon, tangerines, et), mangoes, avocadoes, and other fruits; Sugar cane
Drinks	Fresh Milk; Coffee; Tea; Soda; Beer, Other Alcoholic drinks; Other drinks	Fresh milk; milk products (cream, yoghurt, cheese, etc.); Canned milk/milk powder; Tea dry, Coffee and Cacao, Other raw materials for drink; Bottled/canned soft drinks (soda, juice, water); Prepared tea, coffee; Bottled beer; Local brews; Wines and Spirits

Table F2

Household Descriptive Statistics

Variables	Uganda				Tanzania			
	Rural sector		Urban sector		Rural sector		Urban sector	
	Mean	Std Dev	Mean	Std Devi	Mean	Std Dev	Mean	Std Dev
Head male	0.78	0.42	0.72	0.45	0.78	0.42	0.75	0.44
Age of head	41.76	14.50	38.84	13.17	44.86	14.27	43.00	14.26
Age2 of head /1000	1.95	1.40	1.68	1.22	2.22	1.47	2.05	1.40
Head attended school	0.88	0.33	0.93	0.25	0.81	0.39	0.92	0.27
Polygamous head	0.22	0.41	0.16	0.37	0.14	0.35	0.08	0.27
Married non polygamous head	0.59	0.49	0.60	0.49	0.64	0.48	0.63	0.48
Head is occupied in Agriculture	0.65	0.48	0.16	0.36	0.70	0.46	0.12	0.32
Owner-occupier household	0.86	0.35	0.45	0.50	0.88	0.33	0.51	0.50
Electricity in dwelling	0.06	0.24	0.37	0.48	0.08	0.27	0.56	0.50
Mobile phone	0.17	0.37	0.49	0.50	0.47	0.50	0.81	0.40
Household size	5.83	3.02	5.16	2.96	5.31	2.59	4.93	2.81
Number of clusters	570		175		222		151	
Number of observations	2,609		1,067		720		943	

Table F3

Commodity Group Consumption Descriptive Statistics

Variables	Uganda				Tanzania			
	Rural sector		Urban sector		Rural sector		Urban sector	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Budget shares								
Starches	0.5432	0.1486	0.4729	0.1533	0.4435	0.1897	0.4546	0.1511
Meat-and-Fish	0.1941	0.1175	0.2151	0.1189	0.2348	0.1472	0.2192	0.1218
Fat-and-oil	0.0652	0.05	0.0735	0.0477	0.1241	0.0787	0.1070	0.0575
Vegetable-and-fruit	0.1011	0.0758	0.1093	0.0652	0.1194	0.0818	0.1416	0.0788
Drinks	0.0964	0.1026	0.1292	0.0651	0.0782	0.0987	0.0776	0.0852
Quantities								
Starches	59.3814	47.5773	40.1786	31.4958	35.4814	204.0351	33.2347	348.8804
Meat-and-Fish	2.6313	2.8011	2.8319	2.7142	2.6186	2.4177	2.9359	2.8618
Fat-and-oil	1.0587	1.8815	1.1267	1.4142	2.8786	8.0882	4.2674	24.2742
Vegetable-and-fruit	9.5613	13.8187	7.7726	9.0138	6.0182	6.519	7.0559	29.65693
Drinks	4.7867	7.8922	4.9431	6.1915	3.1675	6.7778	2.9369	9.1728
Unit values								
Starches	265.0909	150.4073	373.3037	200.2825	423.0701	330.9384	850.6657	375.7763
Meat-and-Fish	1948.126	875.2578	2234.24	919.9349	2092.322	1256.715	3517.778	19482.93
Fat-and-oil	1898.984	935.3022	1985.474	919.092	1549.265	1207.012	3585.168	65087.21
Vegetable-and-fruit	501.7396	473.8837	684.1864	698.1483	529.5257	470.9681	877.7565	647.0821
Drinks	1079.949	4102.286	1200.661	1285.441	4043.006	9071.244	4640.637	16.46904

Table F4

Price and Expenditure Elasticities of Demand: Uganda

	Rural sector						**Urban sector**					
	Price elasticities of demand (Own-price elasticities on diagonal)					**Expenditure elasticity of demand**	**Price elasticities of demand (Own-price elasticities on diagonal)**					**Expenditure elasticity of demand**
	Starches	Meat-and-Fish	Fat-and-oil	Vegetable-and-fruit	Drinks		Starches	Meat-and-Fish	Fat-and-oil	Vegetable-and-fruit	Drinks	
Starches	-0.5261***	0.0072	-0.0187*	-0.0195*	-0.0794***	**0.9088*****	-0.6876***	0.2619	-0.0286	-0.0199	-0.1117***	**0.8698*****
Meat-and-Fish	-0.1287***	-0.9631***	-0.0523**	-0.0367	-0.1324***	**1.1827*****	0.4132***	-1.2861***	-0.0456	-0.0222	-0.3697***	**1.2140*****
Fat-and-oil	-0.1041	-0.0842	-0.1365	0.1165**	-0.1492**	**0.8136*****	-0.1600	-0.0484	-0.0930	-0.0710	-0.0677	**0.8187*****
Vegetable-and-fruit	-0.1466**	-0.0323	0.0638*	-0.4178***	-0.1289***	0.9863***	-0.1118	0.0187	-0.0555	-0.3470***	-0.0671	0.9239***
Drinks	-0.6521***	-0.2866***	-0.1316***	-0.1656***	-0.3775***	**1.2863*****	-0.6063***	-0.6308***	-0.0729	-0.0965	-0.1151	**1.2876*****

Notes: Standard errors in brackets. Bold entries correspond to rejection of Ho: e=1. Significance level: * (10%), ** (5%), *** (1%)

Table F5

Price and Expenditure Elasticities of Demand: Tanzania

	Rural sector						Urban sector					
	Price elasticities of demand (Own-price elasticities on diagonal)					Expenditure elasticity of demand	Price elasticities of demand (Own-price elasticities on diagonal)					Expenditure elasticity of demand
	Starches	Meat-and-Fish	Fat-and-oil	Vegetable-and-fruit	Drinks		Starches	Meat-and-Fish	Fat-and-oil	Vegetable-and-fruit	Drinks	
Starches	-0.615***	-0.1857***	0.0004	-0.0269**	-0.1552***	**1.0472*** **	-0.3884***	-0.0663**	-0.0537***	-0.1090***	0.0033	**0.8842*** **
Meat-and-Fish	-0.4477***	-0.7187***	-0.2002***	-0.0679***	-0.0460*	**1.2657*** **	-0.2904***	-0.8682***	0.0059	-0.0341	-0.1991***	**1.2205*** **
Fat-and-oil	0.1719***	-0.2373***	-0.2324***	0.3181***	-0.0113	**0.6633*** **	-0.192**	0.1032	-0.2738***	-0.0472	0.0146	**0.8047*** **
Vegetable-and-fruit	0.1218**	0.0351	0.3451***	-0.0687	-0.1245***	**0.5475*** **	-0.3781***	0.0074	-0.0508	-0.2818***	-0.0112	**0.9456*** **
Drinks	-0.9305***	-0.1133	-0.0795	-0.2632***	0.1419	**1.1593*** **	-0.2263	-0.6068***	-0.0461	-0.0883	-0.7725***	**1.4242*** **

Notes: Standard errors in brackets. Bold entries correspond to rejection of Ho: e=1. Significance level: * (10%), ** (5%), *** (1%)

Appendix G. Yield Response Functions: Estimates Using Household Survey Data

(The primary author of this appendix is Dr. Scott Borger.)

One potential path for development of the simple approach of extrapolating trends in the domestic production of food commodities is to estimates the relationships between yield and area harvested and their determinants so that model users can change baseline projections of the determinants rather than of the productive outcome itself. For example, yield presumably rises with the amount of fertilizer applied to agricultural plots, and if a "yield response function" that captured this relationship is available, the user could input scenarios for fertilizer use into the model. Estimates of yield response functions are developed in this appendix using survey data on households in Nigeria and Tanzania that engaged in agricultural production activity. Results are compared to the previous literature on yield response functions. The appendix concludes with a discussion on why yield response functions have not yet be incorporated into the trend projection model.[58]

OVERVIEW

Agricultural production varies from year-to-year based on a multitude of factors, including the total area to be planted, the choice of crops, the quality of seeds, the quantity of fertilizer applied, use of pesticides and/or herbicides, the number of days spent preparing the field, and the quality of the soil (among others). We focus here on the impact of these factors on the yield of a food commodity per area planted. There are two basic ways that the relationship between yield and its determinants can be assessed. Controlled experiments can be conducted in which a crop is grown on plots (usually at research stations) under identical conditions, except that one plot applies an input (e.g. fertilizer) and one does not, or the input is applied at different levels of intensity. Alternatively, data from surveys of actual farming activity can be analyzed. Because actual farming activity does not correspond to controlled experiments, the survey should ideally provide data on all potentially influential inputs.

[58] We only estimate yield functions using household survey data on crop commodity production, not area harvested functions.

We use here data from two recent household surveys conducted in Nigeria and Tanzania to estimate yield response functions, more specifically the elasticities of yield with respect to each of its observed determinants (fertilizer, herbicides, pesticides, animal labor, human labor, etc.) Each household in the surveys that engaged in agricultural production had one or more plots devoted to the production of one or more food commodity crops. The surveys provide data on inputs for each plot that the household farmed, and the crop output from the plot in kilograms. Yield is derived as the ratio of crop output to plot size. We begin with a conceptual model of how a farmer makes decisions with respect to input use.

CONCEPTUAL MODEL OF INPUT DECISION MAKING

The productivity of agricultural plots in sub-Saharan African depends on exogenous, long-term factors that are not in the direct control of the farmer (e.g., soil type, climate, access to road and markets). However, productivity also depends on factors that are within the control of the farmer (e.g., the type and quantity of seeds planted, the amount of labor, capital, fertilizer or other inputs used). Although purchasing a new plot with higher quality soil or constructing a new road to increase a community's access to markets is possible, these changes are better characterized as long-term rather than short-term decisions. On the other hand, the farmer's choice about crop type or fertilizer use does vary during the year and these choices impact the productivity of aggregate yields at both the intensive margin (e.g., the quantity of fertilizer per plot) and the extensive margin (e.g., the number of farmers that use fertilizer). These short-term household choices are limited by two conditions – the expected profit condition and the cash-in-advance condition.

The Expected Profit Condition

The decision of the agrarian household is limited to those inputs that are expected to be beneficial or profitable to the household (the 'expected profit condition'). This condition does not require the farmer to plant the crop with the highest value for the region, but rather, the crop that is beneficial to the household for a given set of preferences. For example, it may be profitable (e.g., higher yield value from the input exceeds the cost of the input) for the household to add an herbicide to a crop, but given a cultural preference to spend some part of the day in the field, the herbicide may be too costly for these households given the amount of labor available to pull weeds. Or rather, it may be that the plot would produce higher yields of millet, but because the household's preference for cassava and because it does not have access to a market that trades in millet and cassava, the household grows cassava. Instead of requiring the farmer to maximize his profits, we constrain the decision to an expectation that prior to harvest the additional input will increase the crop's yield

The profits of the farmer are the following:

(F1) $$\pi_{j,t} = p_{j,t} y(q_{i,j}, r_t, s)_{j,t} - \sum_i p_{i,t-1} q_{i,j}$$

where *j* is an index of crops, *t* is an index of time, $p_{j,t}$ is the price of good *j* in period *t*, $p_{i,t-1}$ is the price of input *i* prior to growing season, $y(.)_{j,t}$ is the crop's yield per acre and is function of the quantity of inputs per acre, $q_{i,j}$, the level of rainfall during the season, $r_{i,j}$, and s, the quality of the soil.

The expected profit condition requires that for any change in the agricultural inputs controlled by the farmer, $\Delta q_{i,j}$, the change in profits must be non-negative (in expectation).

(F2) $$E_{t-1}(\Delta \pi_{j,t} | \Delta_q) \geq 0$$

Equations (1) and (2) can be combined to get the following result:

(F3) $$E_{t-1} \Delta y_{j,t} \geq E_{t-1} \Delta q_{j,t}$$

The choice of the farmer does not impact the price of the crop or the price of the input, and therefore, when the two profit equations are differenced over the differing input levels the prices drop out.[59] Equation (3) requires that for any added input, the farmer expects the yield to increase from this added input. We test the validity of the hypothesis in equation (3) in Section 4 with an estimation approach that determines whether different inputs have a positive coefficient on the elasticity of that input with respect to a crop's yield.

Additionally, satisfying the expected profit condition is necessary, but it is not sufficient for an input such as fertilizer to be used. It is necessary for the farmer to have the resources to afford the additional fertilizer, which is why we also consider the cash-in-advance constraint.

The Cash-in-Advance Constraint

The decision of the agrarian household is also limited to those inputs that it can afford. If credit is not available to the household for the acquisition of its agricultural inputs, then any cost must be paid out of its savings. The cash-in-advance constraint requires savings of the household (and/or access to credit) is at least as great as the cost of the input:

(F4) $$\sum_i p_{i,t-1} q_{i,j} \leq s_{k,t-1}$$

where $s_{k,t-1}$ is the savings (or credit availability) of household *k* in the period prior to the growing season. This limiting factor is likely to be the reason why many subsistence households fail to purchase inputs that would otherwise be beneficial to its crop's yield.

The Variability of Yields

The variability of a crop's yield that results from the variation in rainfall or political instability can severely impact the ability of the household to purchase inputs in future growing seasons.

[59] Prices are likely to not differ for the same farmer in the same year, but the variation that we observe in our estimation is the variation in input choices among different farmers. The price of the inputs or the commodity could vary based on the cost of transporting the crops to market or transporting the inputs from the market to the field. To account for any differences associated with these costs in the cross-section data, we control for any variation in yield that might be attributed to the distance the plot is from the main road or the distance the plot is from the market.

Some fraction of the savings of the household is used in period *t-1* prior to the realization of the crop yields in period *t*. The larger the fraction of income the household must spend, the more likely that a negative shock to crop production would constrain the household in future periods. For example, suppose a farmer invests higher quality seeds or additional fertilizer at the beginning of the season, but the expected rains do not arrive and the crop yields much less than the farmer had initially expected. Whereas, household production increases in expectation given equation (3), the negative shock to production (ε) from the expected yield reduces savings when the value of the inputs exceeds the value of the additional yield.

(F5) $$\mu - \varepsilon < \sum_i p_{i,t-1} q_{i,t}$$

where μ is the value of the expected yield prior to its actualization. This suggests that households without other sources of income and limited savings would be more susceptible to higher variation in yields where the primary source of this variation prior to the growing season is the variation in year-over-year rainfall. Any attempt by the household to increase its yields by purchasing more inputs could leave its savings in tatters or its creditors in arrears when the growing season experiences below average rainfall totals.

An increase in variability increases the constraints on the household's production. This is because the error terms are likely to be serially correlated. A negative shock during the previous year is likely to constrain input purchases in subsequent years for the household.

DATA AND ESTIMATION APPROACH

We estimate the percentage change in yield with respect to the percentage change in one of its inputs by exploiting cross-section variation in two different household surveys from Tanzania and Nigeria. Although many of the questions asked on these two surveys are identical or very similar, there are some important differences. The Nigerian survey provides very accurate measurements of plot sizes and therefore yields, because it verified plot size using a Global Positioning System (GPS) device. The Tanzania survey relied on a farmer's assessment of plot size, which is subject to greater error.[60] On the other hand, the Tanzania survey provides data on more inputs than the Nigerian survey, in particular on labor input (days the plot was weeded) and soil quality.

Nigerian Household-Level Data

Information on agricultural production in sub-Saharan Africa has been limited by the quality of the survey instruments and the silo nature of sector-specific studies. As part of an effort to increase the quality of agricultural surveys throughout sub-Saharan Africa, the Bill and Melinda

[60] The error introduced by the Tanzania survey's measurement approach could significantly impact derived yield values and estimates of input elasticities. For example, a farmer might have reported a plot size of roughly 1 acre (value recorded in the Tanzania survey) when the actual plot size was 0.8 acres (value recorded in the Nigerian survey.) Errors of this magnitude could have significant impacts on yield values and estimation of elasticity values.

Gates Foundation has committed support to a number of national statistical agencies. Among them are the two surveys used in this paper to estimate the yield elasticity.

The Nigerian National Statistics Agency conducted an agricultural survey between August and October of 2010 in conjunction with the Nigerian General Household Survey (Post-Planting 2010). These data have been made available recently and detail the agrarian behaviors of the household. The benefits of this survey include the combination of the agricultural data with extensive household data, the use of a Global Positioning System (GPS) devise to verify the actual plot size, and a coverage area of both humid and arid climates in the specific region of interest.

Table G1 provides summary statistics on aggregate production of different crops in Nigeria implied by the household survey data and as reported by FAO.[61] These two sources imply significantly different patterns of production across food commodities in Nigeria at the national level. This may be due in part to the representativeness of the sample of households in the survey with respect to agricultural production. The Nigerian household survey used a master sample frame that was constructed from the 2006 Nigerian Census and is representative of Nigerian households.[62] However, a sample that is representative of households is not necessarily representative of the land used for agricultural purposes.[63] It is also true that an estimate by the household of food produced and consumed is likely not to be as accurate as a market-based estimate, such as that from FAO, due to the lack of equipment and need to weigh crops at the household level that introduces measurement error.

The use of production inputs are also reported in table G1. Note that fertilizer was used by some fraction of households for each of the given crops, with the largest share used as inputs in grain production (e.g., millet, maize, rice, and sorghum) and the smallest share used as inputs in root production (e.g., cassava and yams). These latter two crops are labor intensive and are often the crops associated with subsistence agriculture in sub-Saharan Africa rather than production for market sales. The survey reported much lower usage of pesticides and herbicides.[64]

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[61] Total production implied by the household survey is calculated by taking the reported harvests (or expected harvests) for individual households and deriving national production levels using the household weights in the survey sample.

[62] The 2006 Nigerian census has been subject to controversy, and its final results have been disputed.

[63] We also would expect to observe a sample that is more likely to include households with smaller plots. For example, suppose there is a community being surveyed that has one household that owns 100 acres of land and 200 households that own 0.5 acres of land each. With a 95 percent probability, a sample of 10 households in this community will contain only those households with 0.5 acres of land. However, this sample would only represent 50 percent of the land used in production in the community.

[64] There are also significant differences in the type of crops planted in the different regions in Nigeria. Farmers in the Southern regions are more likely to plant root crops whereas farmers in the Northern regions are more likely to plant grains and legumes. For example, almost 40 percent of beans are planted in the North-Eastern states of Nigeria, but this region represents only 13.5 percent of the Nigerian population. Likewise, the South-South and South-East regions represent approximately 27 percent of the Nigerian population, but these regions represent more than 70 percent of the farmers who report planting cassava.

Table G1

Nigerian Food Commodity Production and Input Use

Crop-Type	Implied by Household Survey	FAO Production (2009)	Fertilizer Use	Pesticide Use	Herbicide Use
	(1000s of KGs)		(percent)		
Beans	9,168,777	2,369,580	57.5%	25.0%	18.5%
Cassava	19,336,508	36,804,300	16.7%	4.0%	10.0%
Groundnuts	3,639,601	2,969,260	46.4%	18.7%	30.3%
Maize	17,130,206	7,338,840	50.0%	12.5%	26.2%
Millet	6,645,057	4,884,890	63.1%	22.3%	13.9%
Rice	4,111,417	3,402,590	66.1%	13.4%	51.4%
Sorghum	10,472,910	5,270,790	65.3%	16.7%	24.5%
Yams	11,018,478	29,092,000	27.0%	6.7%	16.4%

Tanzania Household-Level Data

The Tanzania National Bureau of Statistics conducted an agricultural survey between June and August of 2009. The sample was selected in two stages with the first stage selection based on the random selection of a village in proportion to the number of villages in a district. The second stage is a random sample of 15 households drawn from a list of agricultural households in the village or enumeration area. The total sample includes 52,635 households in 142 different districts in Tanzania and Zanzibar.

Table G2 gives the Tanzania summary statistics for the aggregate production of different crops as derived from the household survey and as reported by FAO. Similar to the Nigerian aggregate estimates, the pattern of production implied by the household survey differs significantly from that recorded by the FAO. Table G2 also shows that fertilizer use is much lower in Tanzania than in Nigeria.

Table G2

Tanzania Food Commodity Production and Input Use

Crop-Type	Implied by Household Survey	FAO Production (2009)	Fertilizer Use	Pesticide Use	Herbicide Use
	(1000s of KGs)		(percent)		
Beans	184,828	900,000	15.6%	11.4%	8.7%
Cassava	423,095	5,392,360	0.4%	2.2%	1.8%
Groundnuts	397,404	396,769	8.1%	9.0%	6.7%
Maize	8,842,392	3,555,800	13.1%	13.2%	10.2%
Millet	522,262	222,000	2.3%	25.8%	2.3%
Rice	3,029,390	1,346,340	3.9%	2.9%	9.7%
Sorghum	892,833	861,386	0.3%	6.2%	7.1%
Yams	264,903	1,379,000	6.1%	8.2%	16.4%

The advantage of the Tanzanian data is the additional questions asked in the survey instrument. The Tanzanian survey asks questions about the quality of soil and the amount of time family members spent preparing the soil and weeding the plot during the growing season. These questions address some of the critical factors related to agricultural production, but these factors are not asked in the Nigerian survey. Other than hand, the Nigerian survey represents a large and geographically diverse country within the West African region of interest, and the Nigerian data is likely to be more representative of West African production than the Tanzanian data. The Nigerian survey also includes GPS information about the size of the plot. The increased plot size precision increases the precision of the productivity measure of yield per acre. By considering the estimates in both surveys, the impact of the omitted variables in the Nigerian data can be estimated from excluding these variables in the Tanzanian estimates.

Cross-Section Estimation Approach

The data on agrarian households provides an opportunity to understand the yield variation among a variety of crops in Nigeria. The productivity of different crops depends in part on the decisions of the household (e.g., crop-type, land used, inputs) and in part on exogenous factors (e.g., quality of the soil and the weather). The productivity of a plot (yield/size of plot) is a function the inputs such as seed quantity, seed type, fertilizer quantity, pesticide use, herbicide use, capital, and labor as well as exogenous factors such as the quality of the land and the weather.

The farmer has two primary decisions to make. The first is the decision of which crop to plant, when to plant, and the quantity of seed planted. The crop choices are based on the household's preferences and the value of the crops if they are able to be sold in the market. The timing is specific to different soils and climates in different regions. The quantity to plant is based on expected land use, and whether the costs of the seeds and other required inputs can be covered by the household in advance of harvest or through an extension of credit during the growing season.

The second decision is related to the quantity of inputs that will be used during the season. The farmer chooses the quantity of each input. The choice is the quantity of fertilizer, pesticide, herbicide, labor input, and capital input. This decision is based on the market price, the type of crop planted, and the availability of credit. If credit is not available, then the decision is limited by the cash-in-advance constraint. Note that this constraint is likely to be binding for many farmers in the survey. Among those who reported planting one of the main crops in Nigeria, only one percent used credit for the purchase of some or all of their inputs.

The analysis considers which factors contribute to or are correlated with higher yields per square meter. We use the household's reported harvest (or expected harvest) in kilograms and divide those yields by the size of the plot as determined by a GPS devise that was used by those conducting the survey. A key variable of interest is the impact of fertilizer use on the productivity of the crops. The amount of fertilizer used is also measured in kilograms and is divided by the size of the plot. The other covariates considered in the analysis are binary dummy variables indicating whether the household used herbicides, pesticides, animals, or tractors, and whether the household was able to use its land as collateral. The latter control variable is required to control for differences in how land can be used among different tribal regions. We estimate the following equation:

(F6) $$y_{ijk} = \beta_{0,k} + \beta_{1,k} f_{i,j,k} + z_{ijk}\beta_{z,k} + \gamma_{ijk}$$

where *i, j* and *k* are indices for the household, the region, and the type of crop planted, respectively, and z is an index of the binary variables previously described. The variable y_{ijk} is the natural log of the yield of crop *k* in kilograms per square meter, $f_{i,j,k}$ is the natural log of the amount of fertilizer used in kilograms per square meter, γ_{jk} is the Nigerian regional dummy variable for region *j* and for crop *k*. The regional dummy variables control for the variation for taste preferences, soil quality, and rainfall differences by region. Rainfall is an input that is of crucial importance to African agricultural production.[65] Data on rainfall experienced by plots is not provided in the surveys. The regional dummy variables will control to some extent for differences in rainfall across plots in the sample.

[65] See, for example, Ayanlade et al. (2009), who argue that climate variability is the most important determinant of yields in Nigeria and other parts of West Africa.

EMPIRICAL RESULTS ON THE YIELD FUNCTION

Estimates Based on the Nigerian Household-Level Data

Table G3 provides a summary of the coefficients estimated with the Nigerian household data. The most striking result is that fertilizer use is positive and statistically significant for all food commodities. The elasticity of yield with respect to fertilizer ranges from 2.2 to 5, so that a 10 percent increase the amount of fertilizer applied to the plot increases the yield by between 2.2 and 5.0 percent, with the smallest impact for beans and the largest impact for groundnuts. The estimation approach does omit two critical factors in the production of these crops that are likely to be correlated with fertilizer use. First, the Nigerian survey did not ask the respondent about the quality of soil. Even though such a measure of soil quality has limitations due to the fact that the information is self-reported, it does provide some information about the quality of the plot. This omitted variable problem likely upwardly biases the impact of fertilizer on yield, since households that own plots with high quality soil are likely to have experienced more bountiful harvests in pervious growing seasons. These higher-yielding harvests are likely to be correlated with the ability of the farmer access credit or to pay for the fertilizer expenses out-of-pocket. The second omitted variable in this identification approach is the length of time household members or hired persons spend weeding the plot. This omitted variable too is likely to upwardly bias the impact of fertilizer on yield since households that use additional inputs are more likely to increase the value of those additional inputs by also increase the amount of labor input into the plot. The estimates in table F3 likely represent an upper bound for the yield elasticity of fertilizer.

Table G3 also provides yield elasticities for several other inputs. These elasticities are coefficients on binary dummy variables, so their quantitative interpretation is different from that for fertilizer. The coefficient gives the percentage increase in yield if the input was used in production. For example, in the case of cassava, the use of pesticide, animal labor, and tractors increases yield by 82%, 185%, and 34% respectively. Unlike the case of fertilizer use, these elasticities are not consistently significant across food commodities. However, several are positive and statistically significant.

Table G3

Analysis of Nigerian Agricultural Inputs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	**Maize**	**Cassava**	**Beans**	**Sorghum**	**Millet**	**Yams**	**Groundnuts**	**Rice**
Fertilizer	0.250***	0.220***	0.218***	0.231***	0.249***	0.350***	0.501***	0.235***
(ln of kg/acre)	(0.0253)	(0.0332)	(0.0183)	(0.0204)	(0.0278)	(0.0582)	(0.0405)	(0.022)
Pesticide	-0.0629	-0.82***	-0.39***	-0.36***	-0.207	-1.98***	0.0773	0.242
	(0.171)	(0.289)	(0.105)	(0.130)	(0.162)	(0.407)	(0.329)	(0.212)
Herbicide	-0.0418	-0.142	0.501***	0.194*	0.827***	-0.88***	-0.107	-0.42***
	(0.143)	(0.196)	(0.0976)	(0.113)	(0.177)	(0.298)	(0.249)	(0.147)
Animals	0.363**	1.845**	-0.00537	0.473***	0.247*	-1.149**	-0.323	-0.51***
	(0.168)	(0.727)	(0.0917)	(0.116)	(0.134)	(0.547)	(0.274)	(0.170)
Tractors	0.328	0.342**	0.0571	-0.328*	0.260	0.891***	1.231**	-0.183
	(0.217)	(0.149)	(0.144)	(0.194)	(0.198)	(0.287)	(0.594)	(0.168)
Constant	-0.459**	0.355	-0.87***	-0.82***	-1.12***	0.879**	0.589	0.658***
	(0.211)	(0.262)	(0.186)	(0.191)	(0.287)	(0.431)	(0.438)	(0.197)
Observations	1,251	1,133	1,882	1,430	903	274	512	519
R-squared	0.113	0.186	0.114	0.142	0.178	0.396	0.321	0.239

Notes: *** p < 0.01, ** p < 0.05, * p< 0.01. Standard errors in parentheses.

Estimates Based on the Tanzanian Household-Level Data

Table G3 provides a summary of the coefficients estimated with the Tanzanian household data. Most of the estimates of the yield elasticity with respect to fertilizer are positive and statistically significant. Elasticites for number of days weeding are also positive and significant for most of the crops, suggesting that this input is very important for agricultural production. These results demonstrate that the omitted variables in the Nigerian results upwardly bias the results on fertilizer use. When the quality of the soil and the labor input variables are included, the impact of fertilizer use on crop productivity is almost halved. Fertilizer no longer has a positive impact on groundnuts, but fertilizer's impact on millet, rice and beans is equal to or as large as the estimates in the Nigerian data. For crops for which the quality of the soil has a positive impact on yield (maize and sorghum), the impact of fertilizer was significantly smaller. This suggests that the omitted variable of soil quality in the Nigerian data has some impact on the magnitude of the response of fertilizer to yield.

Table G4

Analysis of Tanzania Agricultural Inputs

VARIABLES	**(1)** **Maize**	**(2)** **Rice**	**(3)** **Sorghum**	**(4)** **Millet**	**(5)** **Cassava**	**(6)** **Bean**	**(7)** **Groundnut**	**(8)** **Yam**	**(9)** **Cottonseed**
Inorganic Fertilizer (ln of kg/acre)	0.124*** (0.0100)	0.215*** (0.0282)	0.127* (0.0645)	0.238*** (0.0593)	0.0980* (0.0526)	0.644*** (0.0805)	-0.132*** (0.0463)	0.132 (0.1120)	0.478*** (0.0852)
Organic Fertilizer (ln of kg/acre)	0.0352*** (0.0063)	-0.00083 (0.0224)	0.128*** (0.0483)	0.0364** (0.0161)	0.0799* (0.0422)	0.124** (0.0545)	0.184*** (0.0319)	-0.0163 (0.0710)	-0.0993*** (0.0199)
Days Weeding	0.0897*** (0.0140)	0.119*** (0.0308)	-0.0264 (0.0450)	0.136** (0.0581)	0.209*** (0.0453)	0.247*** (0.0672)	0.0897 (0.0574)	0.159* (0.0874)	-0.192*** (0.0432)
Tractor	0.596*** (0.1990)	0.359*** (0.1160)				-0.41*** (0.1100)	-0.649*** (0.1760)	-1.21*** (0.4400)	-0.129 (0.0983)
Livestock	0.0547 (0.0641)	0.214* (0.1300)	0.294*** (0.1090)	-0.212 (0.2260)	0.172 (0.2750)	1.012*** (0.3350)	-0.194 (0.2600)	0.666*** (0.2550)	-0.216** (0.0907)
Pesticides/ Herbicides	0.216*** (0.0465)	-0.248** (0.1000)	0.584*** (0.1530)	-1.016 (0.6830)	0.00365 (0.1200)	0.405 (0.2960)	-0.175 (0.7140)		0.317*** (0.0777)
Good Soil	0.202*** (0.0266)	-0.0665 (0.0632)	0.119* (0.0641)	-0.32*** (0.1090)	0.122 (0.0871)	-0.166 (0.1370)	0.0163 (0.0923)	-0.113 (0.1240)	0.0018 (0.0759)
Fallowed Plot	0.186*** (0.0451)	-0.38*** (0.1000)	-0.70*** (0.1150)	0.836*** (0.1530)	-0.68*** (0.2070)	0.154 (0.1580)	0.15 (0.1340)	0.0268 (0.1890)	-0.00424 (0.0827)

Notes: *** p < 0.01, ** p < 0.05, * p< 0.01. Standard errors in parentheses.

We have also estimated the Nigerian and Tanzanian yield functions in which use of fertilizer is captured by a binary dummy variable rather than the number of kilograms of fertilizer applied to the plot. In the case of Nigeria, coefficients on fertilizer use are statistically significant for all food commodities: fertilizer use increases yield by 22-25% for maize, cassava, beans, sorghum, millet, and rice, by 35% for yams, and by 47% for groundnuts. In the case of Tanzania, fertilizer use was statistically significant under this approach only in the case of maize (16%), sorghum (69%), and beans (85%).

Household Survey Estimates versus Controlled Experiment Estimates

The household survey data give estimated yield responses to fertilizer use that are generally statistically significant and relatively quantitatively modest. Nigerian elasticities range from 22% to 50%, and Tanzanian elasticities from 13% to 64%. However, yield responses obtained through controlled experiments are typically much higher in magnitude than these elasticities. Yanggen et al (1998) summarize an extensive literature on yield responses to fertilizer in African countries, most of which is based on controlled experiments at agricultural research stations. Maize, millet and sorghum yields typically rise by over 100% when fertilizer is applied, and rice yield by between 50-100%. Only groundnut yield response, which rises by 43% on average in controlled experiments, is consistent with the response estimated on Nigerian household data.[66] It is perhaps not surprising that yield responses derived from controlled experiments are significantly larger than those estimated from actual (uncontrolled) production activity. Controlled experiments may fail to fully simulate the constraints faced by actual producers and be based on overly-ideal conditions that are difficult to replicate in actual productive activity.

INCORPORATING YIELD RESPONSE FUNCTIONS INTO THE TREND PROJECTION MODEL

Even though key elasticity values have been obtained that are necessary for incorporating yield response functions into the trend projection model, several challenges remain to be overcome in order to achieve this:

- *Inability to set baseline projections for yield inputs.* Although time series on consumption of fertilizer at the national level is available for African countries, time series data on fertilizer consumption by crop is not available. It has also not proven possible to obtain a breakdown of fertilizer consumption by crop for a recent year for any country. Time series for the other yield

[66] Recent controlled experiments provide evidence for Nigeria. Agbaje and Akinlosotu (2004) conducted controlled experiments on the response to fertilizer of tuber crops (e.g. cassava and yams) in Southwest Nigeria and found a negative impact of fertilizer on tuber yields when planted late in the season and no impact when the crops were planted early in the season. Ojeniyi et al. (2009) found a positive impact on tuber yields when oil palm bunch ash (an inorganic fertilizer) was applied to cassava.

inputs are not available even at the national level. At present, there is no way to credibly develop baseline projections of yield inputs.[67]

- *Uncertainty on correct values for yield elasticities with respect to fertilizer.* The relatively small elasticities estimated from the household survey data imply that unless growth in future fertilizer use achieves very high levels, the contribution of fertilizer to boosting yields will not be very significant. However, the elasticities obtained from controlled experiments suggest that for several crops, the contribution of fertilizer growth could be much higher, in some cases by a factor of 5. The issue of which elasticity values to use is crucial for determining whether future growth in fertilizer use will have a significant impact on yield growth.

[67] See Naseem and Kelly (1999) for a review of trends in fertilizer use in sub-Saharan Africa that reveals these data limitations.

Appendix H: Nontraditional Crops in East African Agriculture

The FTP model focuses on food commodities that are of significance to domestic consumption in East African countries. One sector that might offer significant opportunities for growth in the agricultural sector is non-traditional crops. These crops are defined to include bananas, chilies and peppers, cocoa beans, coffee, green beans, mangoes and guavas, oranges, mandarins, pineapples, plantains, pyrethrum, seed cotton, sesame seed, sisal, sugar cane, sunflower seed, tangerines, tea, tobacco, watermelons, and some specialized vegetables and fruits. There is some overlap between the FTP model and non-traditional crops as bananas, plantains, and sesame seed are included in both.

Table H1 gives data on the importance of non-traditional crops in East African countries during 1990-2009. The ratio of non-traditional crop area to total crop area is used as a measure of importance. Burundi and Uganda have had the highest ratios historically, due to the large-scale cultivation of bananas and plantains in those countries. There has been no increase in the relative importance of non-traditional crops in terms of crop area during this period.

Table H1

Share of Non-Traditional Crops in Crop Area Harvested: East African Region

	1990	1993	1995	2000	2005	2006	2007	2008	2009
Burundi	33%	29%	27%	36%	32%	36%	36%	36%	28%
DRC	16%	15%	14%	12%	12%	12%	12%	12%	11%
Eritrea		9%	6%	4%	9%	4%	5%	3%	3%
Ethiopia		13%	9%	8%	8%	10%	10%	10%	11%
Kenya	15%	15%	14%	16%	15%	15%	17%	18%	17%
Malawi	12%	14%	14%	10%	12%	10%	11%	11%	12%
Mozambique	5%	6%	5%	6%	14%	14%	15%	15%	13%
Rwanda	32%	34%	40%	26%	25%	25%	25%	25%	24%
Tanzania	21%	20%	19%	19%	17%	17%	17%	16%	16%
Uganda	43%	43%	42%	42%	40%	39%	40%	40%	39%
Zambia	13%	15%	12%	12%	20%	15%	18%	22%	17%
East Africa Region		**19%**	**17%**	**17%**	**17%**	**17%**	**18%**	**18%**	**17%**

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