Food Policy 36 (2011) 795–804

Contents lists available at SciVerse ScienceDirect

Food Policy

journal homepage: www.elsevier.com/locate/foodpol

Agricultural growth, poverty, and nutrition in Tanzania

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ARTICLE INFO

Article history:
Received 3 December 2010
Received in revised form 26 August 2011
Accepted 8 September 2011
Available online 10 October 2011

Keywords:
Economic growth
Poverty
Undernourishment
Computable general equilibrium modeling
Tanzania

ABSTRACT

Rapid economic growth does not appear to have significantly improved poverty and nutrition outcomes in Tanzania. We link recent production trends to household incomes using a regionalized, recursive dynamic computable general equilibrium and microsimulation model. Results indicate some inconsistency between recent growth and poverty measurements in Tanzania. We also find that the structure of economic growth may have constrained the rate of poverty reduction. Agricultural growth has been driven by larger-scale farmers who are less likely to be poor; and has been concentrated among crops grown in specific regions of the country. Slow expansion of food crops and livestock also explain the weak relationship between agricultural growth and nutrition outcomes. We find that accelerating agricultural growth, particularly in maize, strengthens the growth–poverty relationship and enhances households' caloric availability, while also contributing significantly to growth itself.

Introduction

Although Sub-Saharan Africa experienced unprecedented economic growth in the decade prior to the recent global crisis, this did not always lead to significant reductions in income poverty. National poverty rates have, for example, remained virtually unchanged in fast growing countries like Mozambique (DNEAP, 2010) and Tanzania (NBS, 2010). Moreover, nutritional indicators have sometimes been unresponsive even when poverty did decline. For example, Uganda saw only modest improvements in their nutrition indicators, despite strong economic growth (World Bank, 2010). Such mixed results among Africa's stronger performers suggest a possible disconnect between economic growth and changes in income poverty and households' nutritional status.

Tanzania provides an interesting case study. National gross domestic product (GDP) grew at 6.6% per year during 1998–2007 (MOFEA, 2008), with strong growth in agriculture (4.4%), where most of the country's poorer population derive their livelihoods. Yet despite rapid economic growth, Tanzania's national poverty headcount rate fell by only 2.1 percentage points from 35.7% in 2001 to 33.6% in 2007 (NBS, 2010). The same survey data reveals equally disappointing nutrition outcomes, with the share of the population consuming insufficient calories falling from 25.0% to 23.5%.[1] This raises two questions. First, why did rapid growth not translate into larger poverty reduction? And second, what is the contribution of agricultural growth in reducing poverty and undernourishment?

To address these questions, we link poverty and "nutrition" (or household caloric availability) models to an economywide model of Tanzania and use this combined framework to examine how the structure of economic growth might be causing the slow improvements in poverty and undernourishment. We then compare alternative sources of agricultural growth (i.e., at the subsector-level) in terms of their influence on poverty and household caloric availability. We find some inconsistencies between economic growth and income poverty accounting in Tanzania. However, the slow poverty reduction in Tanzania can be partly explained by the structure of agricultural growth, which has favored larger-scale farmers in specific regions of the country. Had growth been driven by certain underperforming food crops, particularly maize, national and agricultural growth would have been more effective at reducing poverty and undernourishment. Structural

[1] Calorie-deficiency rates reflect the share of the population that had less than 2550 kcal available per male adult (aged 19–59) equivalent. To ensure consistency with the Tanzanian National Bureau of Statistics (NBS) we use this value throughout as the calorie line at which undernourishment rates are measured. This is higher than the calorie line typically recommended by institutions such as United Nations University, World Health Organization, and Food and Agriculture Organization of the United Nations (UNU, WHO, and FAO, 2004) (e.g., for Tanzania the recommended calorie line is 1740 kcal). Hence, in the appendix we provide comparative estimates results at this lower calorie line.

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0306-9192/$ - see front matter
doi:10.1016/j.foodpol.2011.09.002

characteristics of growth therefore explain part of apparent disconnect between growth, poverty and nutrition outcomes in Tanzania.

The paper is organized as follows: Section 'Introduction' reviews the literature on the links between economic growth, poverty and household caloric availability. Section 'Modeling growth, poverty, and nutrition in Tanzania' describes the modeling framework and Section 'Poverty and nutrition outcomes under alternative agricultural growth paths' presents the simulation results. The final section summarizes our findings and policy recommendations.

Linking economic growth to poverty and nutrition outcomes

Growth and poverty

There are already numerous literature reviews on the link between economic growth and poverty; hence we will not attempt to do the same. In short, however, cross-country studies indicate that growth is generally good for the poor (see Dollar and Kraay, 2002), but that poverty–growth elasticities (PGEs) – defined as the percentage decline in poverty caused by a 1% increase in per capita GDP – vary widely between countries. One explanation for this variation is inconsistencies between national accounts and survey data on which growth and poverty estimates are respectively based (see Ravallion, 2001). However, several studies highlight the importance of the sectoral structure of growth as a key determinant of changes in the income distribution and hence also the PGE (Ravallion and Datt, 1996; Mellor, 1999). In this regard, agricultural growth is particularly important in determining the pace of poverty reduction in developing countries (Diao et al., 2010; Valdés and Foster, 2010). The coexistence of rapid agricultural growth and slow poverty reduction in Tanzania is thus at odds with the literature, and we will investigate this more closely in this paper.

Growth and food security

Fewer studies draw the link between growth and nutritional outcomes.[2] Food security includes three dimensions: "availability" of sufficient quantities of domestically produced or imported food; "access" to sufficient resources to acquire a nutritious diet; and "utilization" of food through adequate diet, water, sanitation and health care (Heidhues et al., 2004).[3] Conceptually the link between growth and food security is similar to that between growth and poverty, at least in terms of the access dimension: economic growth raises disposable incomes and thus consumers' ability to purchase more or better quality food. However, while the argument that growth improves food security is straightforward, the causal mechanism is not well understood analytically or quantified empirically (Timmer, 2000).

Timmer (2000) presents a theoretical framework that allows for a clearer understanding of these causal mechanisms, with a focus on caloric availability. The starting point is a semi-logarithmic calorie–income relationship for a representative consumer where income determines caloric intake conditional on a food price index. Both income and food price shocks may cause the representative consumer to fall below or rise above a notional calorie line, defined in terms of some minimum caloric requirement. Given some prior income distribution in the economy, individual behavior can be aggregated to the national level, which allows for an assessment of the impact of different growth strategies on national food security indicators, conditional on food prices. Timmer's (2000) framework illustrates how the escape from hunger can be accomplished through one or more mechanisms: first, growth causes incomes to grow without changing the income distribution; second, the income distribution improves without changing average incomes; and third, price stabilization policies can be introduced to eliminate the adverse effects of food price shocks. The highly successful East and Southeast Asian "growth with redistribution" strategy, which relied on the stimulation of rural growth and price stabilization, is a good example of a strategy incorporating each of these mechanisms (Timmer, 2000, p. 291).

While Timmer's (2000) framework is useful for understanding the "macro" dimensions of growth and food security, it has limitations as an empirical model that is also sensitive to impacts at the "micro" level. First, the simulations in his model assume a hypothetical change in the income distribution due to growth, which itself remains undefined in terms of its structure or extent. The model therefore lacks a mechanism for understanding how different growth paths (e.g., agricultural-led versus manufacturing-led) might affect the level and distribution of household incomes. A model that is disaggregated across economic sectors and that explicitly links household incomes to individual sectors via factor markets would allow us to distinguish between sources of economic growth. Second, while the framework considers the access (demand) dimension of food security, it fails to consider the availability (supply) dimension within the same integrated framework. A general equilibrium model would not only combine demand and supply, but also provide insight into endogenous price formation. This is an improvement on models where prices are treated as exogenous.[4]

A third issue warranting further discussion is the modeling of consumption behavior. When analyzing the relationship between changes in household income and changes in caloric availability it is standard practice to use parametric methods to estimate calorie demand functions and their associated calorie–income elasticities. Surveys by Strauss and Thomas (1995) and Hoddinott et al. (2000) show these elasticities to generally be inelastic and in the range 0.3–0.5. This is also true for Tanzania, where Abdulai and Aubert (2004) estimate a calorie–income elasticity of 0.5 (i.e., a 1% increase in household incomes leads to a 0.5% increase in calorie intake). Nonparametric methods, however, reveal strong nonlinearities in the calorie–income relationship, with lower-income households often displaying higher calorie–income elasticities than wealthier households (see Strauss and Thomas, 1995; Subramanian and Deaton, 1996; Hoddinott et al., 2000). For example, in Fig. 1 the calorie–income curve for Tanzania, which we estimated using the 2000/2001 Household Budget Survey (HBS) (NBS, 2002), becomes noticeably flatter once a sufficient amount of calories is obtained (this also happens to be in the vicinity of the median per capita income in Tanzania).

It follows that growth favoring higher-income households will not raise average caloric availability in the economy by as much as growth favoring households at the lower end of the income distribution. A model that assumes that caloric availability of households is equally responsive to price or income shocks across the entire income spectrum is likely to misrepresent the impact of growth on average caloric availability. Such a model may under- or

[2] The discussion here focuses on the impact of growth on nutrition. Improved nutrition may also raise labor productivity and hence lead to higher economic growth (see Arcand, 2001). We do not analyze this reverse link.

[3] The term "availability" here implies food availability in the "macro" supply sense of the word. This should not be confused with the term "caloric availability", which is used when household expenditure survey data are used to measure caloric intake by households. Such surveys often overstate the true caloric intake of the household as not all food purchased in necessarily consumed by its members (Smith and Subandoro, 2007); hence the preference for the term caloric availability as opposed to caloric intake.

[4] Ex ante modeling frameworks are generally unsuited to analyzing the "utilization" dimension of food security. Economic growth may improve general health and sanitation in society, but such effects are best evaluated in an ex post context.

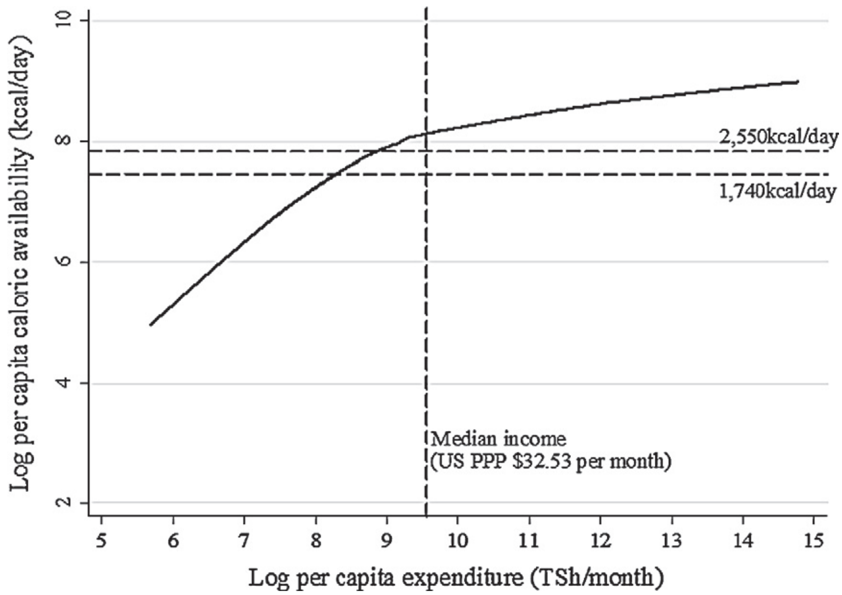

Fig. 1. Nonparametric estimates of income–calorie curve for Tanzania (2001). *Notes*: In 2000/2001 the median per capita income (calculated using adult equivalent household size) was TSh 14,184 per month (NBS, 2002). At the World Bank's purchasing power parity (PPP) conversion factor of TSh436/US$ at the time this was equivalent to US$32.53 per month, which is slightly below the international US$1/day poverty line. *Source*: Authors' estimates using the HBS 2000/2001 (NBS, 2002).

overestimate changes in the incidence of undernourishment, especially when the estimated calorie–income elasticity is not representative of households in the vicinity of the calorie line.

Timmer's (2000) macro-framework usefully illustrates why higher aggregate food prices, in general, have detrimental nutritional effects. However, a national food price index may not necessarily be representative of a poor or undernourished consumer's food basket. Additionally, even when the average food price is unchanged, movements in relative food prices of different food types may have important nutritional effects, which are not adequately captured within a macro-framework. A model that disaggregates food groups will better capture the fact that poorer consumers often allocate a larger share of their income to food types with high calorie contents and a lower cost per calorie. Such a model will also be more sensitive to capturing the effect of policies that lower the cost of calorie-rich foods relative to others. The same line of reasoning applies to other nutrients in a consumer's diet.

To illustrate, Table 1 compares the calorie content of different foods in Tanzania, and shows how the price per 100 kcal varies by product. For example, livestock products have a higher average caloric content per 100 g serving than most other food types, but their higher price makes them an expensive energy source. The remaining columns show the average calories available from different food products for poor and non-poor households. Since average per capita incomes in Tanzania are low, a large share of calories is obtained from foods with low prices per calorie (e.g., maize). The share is higher for poor households.

In summary, households' consumption preferences and behavioral responses to relative food price changes are better captured in a model with detailed representative households and food commodities. We therefore develop an economywide model of Tanzania which is not only highly disaggregated in its food and household accounts, but is complemented by a microsimulation module used to estimate changes in household-level poverty and nutrition (caloric availability) changes. The model is described in more detail in the following section.

It is worth noting that household income growth may not be a sufficient condition for improved nutrition. In India, for example, rapid income growth has not translated into nutritional improvements, with stunting and wasting remaining widespread and per capita caloric availability declining. This deteriorating nutrition cannot be explained by a worsening income distribution or rising food prices (Deaton, 2010). Other plausible explanations include economic transformation away from agriculture (i.e., people require less energy) or improved health and sanitary conditions (i.e., fewer calories are lost to diarrheal disease). However, direct evidence to support these alternative explanations is scant, and so India's nutrition puzzle remains unsolved.

Modeling growth, poverty, and nutrition in Tanzania

Economywide model

We use a recursive-dynamic computable general equilibrium (CGE) model to capture the impact of alternative sectoral growth paths on different households and regions in Tanzania.[5] The economywide impact of growth depends largely on the inter-sectoral linkages. Our model identifies 58 sectors, 26 of which are in agriculture and 10 in downstream agro-processing. Agriculture is further disaggregated across 20 sub-national regions using the 2002/2003 Agricultural Sample Survey (ASS) (MINAG, 2004). This regional detail captures variation in agro-ecological conditions and rural livelihood/cropping patterns. Producers in each sector and region maximize profits when combining intermediate inputs with land, labor and capital. We use nested constant elasticity of substitution (CES) production functions that reflect region-specific technologies (i.e., factor and intermediate inputs) and allow for imperfect substitution between factors. Based on HBS 2000/2001, labor markets are segmented into four education groups (i.e., uneducated, primary, secondary and tertiary). Agricultural land and livestock in each region are separated into small- and large-scale farms using ASS 2002/2003. Given low unemployment levels in Tanzania, especially for educated labor, and labor shortages during peak crop planting and harvesting periods, we assume that labor is effectively

[5] For a detailed specification of the class of CGE model used in our study, see Dervis et al. (1982) and Löfgren et al. (2002).

Table 1
Calorie contents, calorie prices and caloric availability in Tanzania (2001). *Source*: Authors' calculations using expenditure estimates from HBS 2000/2001 and calorie content tables in Lukmanji et al. (2008).

	Average calories per 100 g serving[a]	Mean price per 100 kcal (Tsh)[b]	Average per capita caloric availability by population subgroups		
			Poor[c]	Non-poor[d]	All
Cereals	294	6.3	1390	1885	1687
Maize	288	4.7	1112	1461	1322
Sorghum and millet	287	7.1	194	194	194
Rice and wheat	305	17.2	85	230	172
Root crops	178	5.5	424	423	423
Pulses and oilseeds	443	10.9	196	411	325
Horticulture	49	19.8	106	240	186
Livestock and processed meat	266	26.0	125	318	241
Sugar and other foods	181	13.2	50	178	127
Average/total	217	10.5	2358	3699	3163

[a] No consumption weights applied in calculating average calories per food group.
[b] Averages price is the total expenditure divided by total calorie content per food item.
[c] Poverty line is the 40th percentile of per capita expenditure.
[d] Average caloric availability in non-poor households may be overestimated, which is not uncommon for estimates derived from household expenditure surveys (see Smith and Subandoro, 2007). Our analysis did not include careful identification of outliers given our interest in consumption changes for households close to or below the calorie line.

fully-employed and, like land, is mobile across sectors but not regions. Capital becomes immobile after it has been invested (i.e., a "putty-clay" specification).

Economic outcomes are also affected by trade and movements in market prices. We assume that producers in each region supply their output to national product markets (using a CES aggregation function), which avoids having to model inter-regional trade flows for which no data is available. However, transaction costs separate regional producer and national consumer prices. International trade is captured by allowing production and consumption to shift imperfectly between domestic and foreign markets depending on the relative prices of imports, exports and domestic products. More specifically, we employ CES Armington functions for imports and constant elasticity of transformation (CET) functions for exports. Initial trade patterns are from FAO (2009) and MOFEA (2008). Since Tanzania is a small economy, world prices are fixed. The current account balance is maintained by a flexible real exchange rate.

Trade patterns influence a sector's growth–poverty relationship. Commodities that rely on domestic markets are more likely to experience price declines when production expands, whereas exported commodities are affected less since Tanzania is only a small contributor to global supply. Table 2 shows Tanzania's broad economic structure in 2007. Export-oriented crops, such as sugarcane, are major foreign exchange earners and rely on foreign markets (i.e., the fourth column of the table shows that almost three quarters of output is exported). In contrast, most food crop production is sold in domestic markets. For example, only 2.3% of maize produced in Tanzania is exported, while 11.0% of domestic demand is supplied by imported maize. Finally, outcomes in the model are also influenced by the ease with which producers and consumers can switch between domestic and foreign goods.[6] The sensitivity analysis in the Appendix focuses on the model's tradability assumptions.

Household income and expenditure patterns are important in determining poverty and nutrition outcomes. Households in the model are separated into rural and urban areas, farm and nonfarm groups, and by per capita expenditure quintiles, with farm households further split by region (i.e., there are 110 representative household groups in total). Farm households include those deriving any income from agriculture. Factor incomes are distributed among households based on their factor endowments. Households save and pay taxes (at fixed rates) and the balance of income is used for consumption expenditure. The latter is based on a linear expenditure system (LES) of demand, which allows for non-unitary income elasticities and fixed marginal budget shares. Using expenditure data from HBS 2000/2001, we estimate income elasticities separately for urban and rural households across expenditure quintiles following the approach in King and Byerlee (1978).

Household poverty in the model is therefore affected through both income and expenditure channels. When agricultural production expands, farm households, who derive income from land ownership and on-farm employment, are more likely to benefit from higher crop revenues, although this may be partially offset by falling producer prices and lower returns to factors. Falling prices, in turn, benefit consumers in nonfarm households as well as net-consuming farm households (i.e., those producing less than they consume). In general, however, the use of aggregate household groups in our CGE model prevents a more nuanced analysis of the differential effects on net consumers and net producers within the farm household groups.

Table 2
Tanzania economic structure (2007). *Source*: Authors' calculations using the 2007 Tanzania social accounting matrix.

	Share of total (%)			Intensity (%)	
	GDP at factor cost	Exports	Imports	Exports	Imports
Total GDP	100.0	100.0	100.0	13.7	26.8
Agriculture	31.8	27.9	6.1	18.7	11.4
Maize	4.4	0.4	1.0	2.3	11.0
Sorghum and millet	0.9	0.0	0.0	0.0	0.0
Rice and wheat	3.0	0.4	4.3	2.0	4.2
Root crops	3.3	0.0	0.0	0.7	0.0
Pulses and oilseeds	2.7	1.0	0.1	7.1	1.7
Horticulture	5.2	1.7	0.3	9.0	4.7
Export crops	2.8	16.1	0.3	73.3	14.3
Livestock	5.5	1.2	0.1	4.5	1.4
Other agriculture	4.0	7.0	0.1	40.5	1.8
Mining	3.9	19.0	4.0	82.8	73.1
Manufacturing	8.5	9.9	74.4	10.1	65.4
Agro-processing	5.6	2.5	9.0	3.8	25.9
Other industry	10.4	0.0	0.2	0.0	0.3
Services	45.0	42.5	12.8	12.6	7.6

Notes: "GDP" is gross domestic product; "export intensity" is the share of exports in domestic output; and "import intensity" is the share of imports in total domestic demand.

[6] Production and trade elasticities are from Dimaranan (2006).

The distinction between small- and large-scale farming activities is important insofar as household types (e.g., poor and non-poor) differ in their linkages to these activities. However, in our analysis we assume that that all producers within a certain agricultural subsector benefit equally from a policy intervention and hence experience the same increase in growth. In reality agricultural development policies may explicitly target small or large-scale farmers, in which case the distinction in the model becomes more important.

The model's variables and parameters are calibrated to a social accounting matrix (SAM) capturing Tanzania's economic structure in 2007. Under a recursive dynamic specification of the model certain parameters are updated over time to reflect the demographic and economic changes expected to take place over the simulation period 2007–2015. Three such adjustments occur: first, land and labor supplies increase exogenously based on long-term trends; second, capital accumulation is determined endogenously by converting the previous year's investments into new capital stocks, which are then allocated to sectors/regions based on prevailing profit rate differentials (see Dervis et al., 1982); and finally, sectoral productivity growth is updated according to observed historical trends (FAO, 2009; MOFEA, 2008).

Changes in the level and structure of economic growth in our simulations are achieved by adjusting total factor productivity (TFP) growth in each subsector. Our specification assumes that farmers allocate more of their scarce land and labor resources to sectors whose TFP rises relative to that of others.[7] Changes in production and factor demand therefore depend on the relative factor intensities of each sector.[8] Household incomes are affected differently depending on relative factor endowments, while shifts in consumer demand depend on households' consumption baskets and the estimated price and income elasticities. Total demand and supply are equilibrated via changes in market prices. The results of the model are thus largely determined by the unique structural characteristics of the Tanzanian economy, which are derived from economic data.

Poverty and nutrition modules

Each of the approximately 22,000 households questioned in HBS 2000/2001 is linked top-down to its corresponding representative household in the CGE model. This allows us to estimate changes in poverty and caloric availability at the household-level. While this approach to micro-modeling still assumes constant within-group income distributions, it permits a more nuanced interpretation of the effects of changes in income on poverty and undernourishment rates within household groups than is possible with a CGE model alone.

The poverty module applies percentage changes in each representative household's real consumption of each of the 58 commodities in the CGE model to the corresponding households in the survey. Thus, for each simulation, a new household-specific level of per capita expenditure is estimated, which then serves as a welfare measure in standard poverty analysis. We assume that gains in per capita expenditures are shared equally among household members. At the time of writing, the HBS 2007 had not been released and so we used HBS 2000/2001 survey data for our model's 2007 benchmark year. To emphasize this assumption, we set the poverty line at the 40th percentile of per capita expenditure rather than assume that poverty remained unchanged between 2000/2001 and 2007. Our reported national poverty headcount rate therefore differs from official estimates for either 2000/2001 or 2007. However, our analysis focuses on changes in poverty rather than absolute levels.

The nutrition module is also linked top-down to the CGE model. We use food consumption data from HBS 2000/2001 and caloric content tables from Lukmanji et al. (2008) to calculate initial household caloric availability. CGE model results on changes in food consumption quantities are then applied to the survey data to estimate changes in household caloric availability. We compare both the original and new levels of caloric availability against our calorie line of 2550 kcal per male adult equivalent per day to determine changes in calorie-deficiency rates for each CGE simulation. Individuals whose caloric availability falls below this threshold are deemed 'undernourished'. Equivalence scales are from the United Nations University, World Health Organization, and the Food and Agriculture Organization (UNU, WHO, and FAO, 2004), i.e., both the size and demographic structure of households determine the minimum amount of calories required by each household. In the Appendix we present comparative results for calorie line of 1740 kcal/day.

Poverty and nutrition outcomes under alternative agricultural growth paths

Tanzania's recent agricultural growth performance

Although agricultural GDP expanded at 4.4% per year during 1998–2007 (MOFEA, 2008), growth in the sector remained volatile and was slower than in overall economy. Agriculture's weaker performance has been linked to structural adjustment policies introduced from the 1980s (Danielson, 2002; Meertens, 2000). While these reforms strengthened the role of markets and stabilized prices, their benefits did not extend to the agricultural sector. Agricultural output per capita stagnated during the 1990s, due to inadequate use of fertilizers and modern technologies, and underinvestment in machinery and infrastructure (see Danielson, 2002; Meertens, 2000; Morris et al., 2007; Putterman, 1995; Wiig et al., 2009).

Crop production trends provide further insight into the impact of agricultural growth on poverty and nutrition. More than half of harvested land in Tanzania is allocated to cereals (Table 3). Maize is the dominant staple food crop for the country's large subsistence farmer population. Maize yields remain low (0.88 metric tons per hectare) and per capita production fell during 2000–2007. Wheat production, by contrast, has grown rapidly and is overwhelmingly produced by large-scale commercial farmers in the north of Tanzania using modern inputs. Rice has also performed well and is becoming an important food crop for smallholders in the western and lake regions (MINAG, 2006). However, despite rice and wheat expansion and generally favorable agro-ecological conditions, Tanzania remains a net cereals importer because production has failed to keep pace with rising consumer demand.

Roots, such as cassava and potatoes, are also important food sources and account for almost 15% of Tanzania's harvested land. Root crops have performed well recently with more than 4% annual growth. By contrast, higher-value pulses and vegetables have stagnated, with pulses production declining by more than 4% each year. This was partly offset by expanded oilseeds production throughout the country and by fruit production in the northern and eastern regions. Non-cereal food crop production has therefore been characterized by slow growth in widely-produced crops, and fast growth in regionally-concentrated crops.

[7] This implies that land yields and capital and labor productivity increase concurrently in our simulations. We only report changes in crop yields and production levels since these are often targeted within agricultural growth strategies.

[8] Land and labor are the main factor inputs for all crops. However, food crops (e.g., maize) are often less capital intensive than export crops (e.g., sugarcane), and are less likely to use modern inputs and farming practices (e.g., irrigation). Wheat is also more capital intensive than most other food crops.

Table 3
Historical (2000–2007) and modeled (2007–2015) agricultural production data. *Source*: Authors' calculations Agricultural Sample Survey 2002–2003 (MINAG, 2004), FAOSTAT (FAO, 2009), MINAG (2006), and results from the Tanzania CGE model and poverty/nutrition modules.

	Historical crop production data			Modeled scenarios, 2007–2015			
	Crop land allocation in 2007 (% share)	Annual production growth, 2000–2007 (%)	Yields in 2007, (metric tons per hectare)	Baseline scenario		Agriculture scenario	
				Annual yield growth (%)	Annual production growth (%)	Annual yield growth (%)	Annual production growth (%)
Cereals							
Maize	32.77	2.08	0.88	1.92	2.82	4.39	5.01
Sorghum	7.91	3.31	0.75	2.07	4.46	2.61	5.41
Millet	3.12	0.17	0.54	−3.85	1.67	−1.00	3.71
Rice	6.65	6.24	1.99	4.69	6.79	4.92	7.02
Wheat and barley	0.97	8.49	1.18	9.37	11.56	9.66	11.85
Root crops							
Cassava	8.04	3.54	8.01	3.43	4.28	4.22	5.60
Other roots	6.57	5.26	2.17	6.88	5.42	6.87	6.47
Pulses and oilseeds							
Pulses	9.64	−4.32	0.65	−9.29	−2.65	−6.60	−0.31
Coconuts	3.78	0.00	1.19	−1.74	0.23	−0.05	1.95
Oilseeds	4.62	5.01	0.63	5.94	6.69	5.56	7.89
Horticulture							
Plantains	3.75	0.12	1.83	−2.14	1.19	−0.45	2.88
Fruits	2.03	11.98	4.02	16.91	9.44	15.98	9.90
Vegetables	2.10	0.22	6.74	−1.15	0.58	1.26	3.27
Export crops							
Coffee	1.67	−0.03	0.39	−2.81	−0.86	3.58	5.65
Cashews	0.97	−2.12	0.94	−7.69	−5.84	−1.81	0.15
Cotton	3.59	9.49	0.61	10.20	12.40	10.36	12.57
Sisal	0.56	3.60	0.51	2.33	4.38	3.90	5.98
Sugarcane	0.21	8.47	16.06	10.29	12.50	10.81	13.03
Tea	0.23	3.80	1.59	3.51	5.58	5.12	7.23
Tobacco	0.41	11.39	0.52	13.70	15.97	13.74	16.02
Other crops	0.40	1.76	0.51	−0.22	1.77	1.86	3.90

Notes: Crop yields are targeted by exogenously raising TFP growth rates in the baseline and accelerated agricultural growth scenarios. Production is determined endogenously since factors can be reallocated to other sectors in response to changing productivity levels and relative prices.

Some of the fastest growth rates during 2000–2007 were for export-oriented crops. Traditional exports, such as cotton, sugarcane and tobacco, grew at almost 10% per year. However, these crops are highly concentrated in specific regions. Cotton is mainly produced by smallholders in the western and lake regions (81.5% of national output). Tobacco, another smallholder crop, is produced in the western and highlands regions (82.8%). Sugarcane is mostly produced by larger-scale commercial farmers in the eastern and northern regions (83.8%). Together these three crops generated 17.4% of total merchandize exports in 2007. Coffee and cashew nuts are also major export crops, but their production has declined in recent years. Growth in export agriculture has therefore been driven by the strong performance of a few regionally-concentrated crops.

Finally, livestock and fisheries account for almost a third of agricultural GDP. Fisheries has kept pace with overall agricultural production but livestock has lagged behind crop agriculture. Incomes from cattle and poultry are key income sources for farmers throughout the country, especially for lower-income households (NBS, 2010). Thus, slow livestock growth has implications for households' livelihoods, especially for the poor.

Comparing the current growth path with an accelerated agricultural growth path

To better understand the poverty and nutritional implications of Tanzania's historical growth path, we use the CGE model to produce a "baseline scenario" that assumes recent production trends continue over the period 2007–2015. We compare these results to a hypothetical scenario with accelerated agricultural growth ("agriculture scenario") in which agricultural productivity growth exceeds the baseline trend and is more broad-based (i.e., a wider range of crops and subsectors drive the growth process).

Under both scenarios total harvested land area expands at 2% per year, which is comparable to historical land expansion rates. The model endogenously allocates land in each of the 20 regions across crops so as to maximize returns. TFP for each subsector and region is increased exogenously in order to achieve targeted crop yield growth rates under the two scenarios. The crop yield changes resulting from these exogenous TFP adjustments for 2007–2015 are shown in Table 3. At the subsector-level, modeled yield gains for individual crops are based on estimated yield gaps.[9] To achieve broader-based agricultural growth, yield gains for crops whose yield gaps are narrower and that have performed well in the past (e.g. rice, wheat and certain export crops) improve only marginally in the agriculture scenario, while poor performing crops (e.g., maize, pulses and vegetables) experience larger yield gains, reflecting their greater growth potential.

Table 4 reports the overall GDP growth results of the baseline and agriculture scenarios. The average agricultural GDP growth rate in the baseline scenario is 3.9% per year, which is consistent with observed growth during 1998–2007. In line with historical

[9] The modeled yield gains are broadly consistent with what would be required for Tanzania to achieve the agricultural growth rate targeted under the Comprehensive African Agricultural Development Program (CAADP).

Table 4
GDP growth in the baseline and accelerated agricultural growth scenarios. *Source*: Results from the Tanzania CGE model and poverty/nutrition modules.

	GDP shares in 2007 (%)		Annual GDP growth, 2007–2015 (%)		
	Total GDP	Agricultural GDP	Baseline scenario	Agriculture scenario	Point change from baseline
Total GDP	100.00		6.08	6.59	0.51
Agriculture	31.84	100.00	3.88	5.32	1.45
Maize	4.42	13.87	2.81	5.01	2.19
Sorghum and millet	0.88	2.77	3.81	5.01	1.21
Rice and wheat	3.02	9.48	7.08	7.32	0.24
Root crops	3.27	10.28	4.60	5.84	1.24
Pulses and oilseeds	2.71	8.51	0.45	2.30	1.85
Horticulture	5.20	16.32	2.58	4.47	1.89
Export crops	2.79	8.76	6.70	8.56	1.86
Livestock	5.54	17.39	3.39	4.68	1.29
Other agriculture	4.02	12.62	3.83	4.93	1.09
Mining	3.93		12.37	12.36	−0.01
Manufacturing	8.84		7.35	8.01	0.66
Other industry	10.39		7.08	7.05	−0.03
Services	45.01		6.35	6.43	0.08

Notes: 'Other agriculture' includes forestry and fisheries; 'Other industry' includes construction and utilities.

trends, baseline agricultural growth is driven by crop agriculture with modest growth in livestock. National growth, however, continues to be driven by industry and services. Total GDP grows at 6.1% per year under the baseline scenario, which is comparable to the 6.6% annual growth rate during 1998–2007 (MOFEA, 2008). The baseline scenario therefore reasonably represents the level and structure of Tanzania's recent growth path.

Average agricultural GDP growth rises to 5.3% per year in the agriculture scenario. This growth is broad-based in that, unlike in the baseline, most crops now expand rapidly. Faster agricultural growth generates forward-linkage effects, particularly for food processing, which benefits from increased supply and lower prices of agricultural input. This explains the expansion of manufacturing. Overall, annual national GDP growth increases from 6.1% in the baseline to 6.6% in the agriculture scenario.

We compare the poverty and nutrition effects under each scenario on the basis of two key "deprivation elasticities", namely the poverty–growth elasticity (PGE) (as defined earlier) and the "undernourishment–growth elasticity" (UGE), which measures the percentage change in the calorie-deficiency rate for a given percentage change in per capita GDP.[10] In Tanzania, both these elasticities may be sensitive to whether the per capita GDP estimate is derived from household survey data or from the national accounts; for example, national accounts reports 3.99% annual growth in per capita GDP during 2001–2007, which is well above the 1.32% annual growth in per capita consumption estimated from the household surveys.[11] We therefore report lower- and upper bound estimates of historical PGEs and UGEs in Table 5.

Household survey data suggests that the poverty rate declined by 1.01% per annum between 2001 and 2007 (NBS, 2010), implying that the PGE lies between −0.25 and −0.76 depending on whether national accounts or household survey data is used to measure income changes. The national accounts-based estimate suggests a deterioration of the PGE from −0.82 during the 1990s to −0.25 during the 2000s, whereas the household surveys suggest an increase from −0.57 to −0.76. Understanding these differences is important because they imply different trends in the effectiveness of economic growth to reduce poverty in Tanzania. The calorie-deficiency rate declined by 1.03% per year over the same period, which implies the UGE lies between −0.26 and −0.78.

Table 5 also reports the results from the baseline and agriculture scenarios. Average annual per capita GDP grew at 3.58% and 4.09% under the two scenarios respectively, while poverty declined by 3.68% and 5.39%. The simulation results from the baseline scenario suggest that a PGE of −1.03 is consistent with historical growth trends. This is larger than the historical upper-bound estimate at −0.76, which suggests that economic growth may be overestimated in national accounts and/or that the rate of poverty reduction is underestimated by the household surveys. Under the agriculture scenario the PGE increases to −1.32. The nutrition module, in turn, shows declines in undernourishment of 3.54% and 4.84% in the two scenarios. This suggests a baseline UGE of −0.99, which is also outside the range estimated from historical data. In the agriculture scenario the UGE improves to −1.57.

There are two potential sources of bias in our PGE and UGE results. First, PGEs and UGEs are sensitive to changes in income elasticities. For example, when national average elasticity estimates are applied to all households (as opposed to quintile estimates) then the modeled PGEs and UGEs are consistent with historical estimates. However, while disaggregating income elasticities across quintiles is important (see Fig. 1), a quantile regression approach generates larger standard deviations around elasticity estimates. Second, our baseline scenario replicates historical GDP growth trends for the main economic sectors, but at the detailed agricultural subsector level we have to rely on crop production data. Therefore, our subsector growth structure may deviate slightly from national accounts, since the latter is not reported with sufficient detail.

We do not attempt to use our modeling framework to evaluate the credibility of national accounts or the household surveys – a more detailed ex post analysis is required. Rather, we focus on how the structure of economic growth may have influenced poverty and nutrition outcomes. Our results indicate that accelerated and broad-based agricultural growth greatly strengthens the impact of economic growth on poverty. Moreover, agricultural growth is also more pro-poor than nonagricultural growth since the nonagricultural sector is not the primary driver of accelerated economic growth in the agriculture scenario and yet the PGE increased. The UGE, in particular, rises substantially under the accelerated agricultural growth scenario, which is a reflection of the increased production and consumption of calorie-rich maize, sorghum, millet and pulses.

[10] UGEs measure the change in the population share consuming less than a threshold number of calories (i.e., a deprivation measure). This differs from calorie-income elasticities, which measure changes in absolute calorie intake.

[11] Private consumption, a key component of GDP, is typically larger in national accounts compared to household surveys because it includes a wider range of products and also because surveys are less likely to sample households at the top of the income distribution. National accounts estimates, on the other hand, are prone to error because private consumption is treated as a residual between GDP at factor cost and other components of GDP at market prices (Ravallion, 2001).

Table 5
Historical and modeled poverty- and undernourishment–growth elasticities. *Source*: Results from the Tanzania CGE model and poverty/nutrition modules.

	Initial deprivation rate (%)	Final deprivation rate (%)	Avg. annual% change in deprivation rate (a)	Annual per capita GDP growth (b)	Deprivation-growth elasticity (a)/(b)
Historical data (2001–2007)					
Poverty	35.7	33.6	−1.01	1.32/3.99	−0.25/−0.76
Calorie-deficiency	25.0	23.5	−1.03	1.32/3.99	−0.26/−0.78
Modeled scenarios (2007–2015)					
Baseline scenario					
Poverty	40.0	29.6	−3.68	3.58	−1.03
Calorie-deficiency	23.5	17.6	−3.54	3.58	−0.99
Accelerated agric. growth					
Poverty	40.0	25.7	−5.39	4.09	−1.32
Calorie-deficiency	23.5	13.8	−4.84	4.09	−1.57

Notes: The historical 2001 and 2007 poverty rates are measured at the official poverty lines. The range of elasticities estimated from historical data (column 5) reflects the inconsistent measurement of per capita income changes between national accounts and survey data (column 4). In the modeled scenarios we set the poverty line at the 40th percentile of per capita expenditure (HBS 2000/2001). A calorie line of 2550 kcal per adult equivalent per day applies in both the historical estimates and modeled scenarios.

Table 6
Poverty, undernourishment, and growth effects of agricultural subsectors. *Source*: Results from the Tanzania CGE model and poverty/nutrition modules.

	Deprivation elasticities		Growth-effects	
	Poverty–growth elasticity (PGE)	Under-nourishment-growth elasticity (UGE)	Growth linkage effect	Linkages weighted by size
Maize-led growth	−1.174 (2)	−1.477 (1)	1.095	0.152 (3)
Sorghum and millet-led growth	−1.136 (4)	−1.348 (3)	1.186	0.033 (9)
Rice and wheat-led growth	−1.100 (7)	−1.148 (5)	1.116	0.106 (5)
Root crops-led growth	−1.182 (1)	−1.350 (2)	1.033	0.106 (5)
Pulses and oilseeds-led growth	−1.141 (3)	−1.161 (4)	1.189	0.101 (7)
Horticulture-led growth	−1.118 (5)	−1.092 (6)	1.137	0.186 (2)
Export crops-led growth	−1.096 (8)	−1.057 (7)	1.117	0.098 (8)
Livestock-led growth	−1.075 (9)	−0.969 (9)	1.176	0.204 (1)
Other agriculture-led growth	−1.113 (6)	−1.022 (8)	0.949	0.120 (4)

Notes: 'Other agriculture' includes forestry and fisheries.

Comparing alternative sources of agricultural growth

The previous section illustrated the benefits of broad-based growth. However, further modeling is required to ascertain whether certain agricultural subsectors are more effective than others at improving the poverty and nutritional outcomes of agricultural growth.

Growth within different agricultural subsectors can have different impacts on development outcomes for various reasons. First, sectors differ in terms of their relative factor intensities. Growth in sectors that intensively employ the factors of production typically owned by poor households is more likely to reduce poverty. Similarly, some subsectors produce products that poorer households consume more intensively. Faster growth in these sectors will therefore have a greater impact on poverty for farmers producing these crops, whereas poorer consumers may also benefit from falling market prices. Second, some subsectors produce products that are particularly important for households' nutritional status, such as those that represent low-cost sources of calories or are consumed intensively by calorie-deficient households. While our deprivation elasticities are by definition growth-neutral, growth itself is crucial for reducing poverty and undernourishment. Thus, a third factor concerns growth itself, and the fact that some sectors, due to their downstream production and consumption linkages, can have a greater impact on overall growth. These three criteria are taken into account when we identify subsectors that are most effective at lowering poverty and undernourishment in Tanzania.

For the purpose of the analysis we group agricultural subsectors into nine groups, namely: maize; sorghum and millet; rice and wheat; roots; pulses and oilseeds; horticulture; export crops; livestock; and other agriculture. The growth effects of subsectors are evaluated in a comparable way by running separate sector-specific simulations that generate the same absolute increase in total agricultural GDP by 2015 (measured in base year prices). Small subsectors therefore have to grow faster than large ones in order to order to achieve the same targeted agricultural GDP expansion. Unlike previous scenarios, the following subsector scenarios are "growth-neutral" and do not reflect assessments of yield gaps or growth potentials. The resulting PGEs and UGEs for each subsector are therefore "normalized" so that they are directly comparable with one another.

The results in Table 6 show that the three highest PGEs are for growth led by maize, root crops, and pulses and oilseeds. These crops are important expenditure items for households just below the poverty line and are grown more intensively by poorer farm households. In contrast, the elasticity for rice and wheat-led growth is lower, mainly because these crops are grown in specific regions of the country and, in the case of wheat, by larger-scale farmers who are less likely to be poor.

The UGEs indicate that maize, sorghum and millet, and root crops are most effective at raising household caloric availability per unit of growth. Although pulses and oilseeds have high calorie contents, these are not consumed as intensively by the poor since they are a fairly expensive source of calories (see Table 1). Livestock has the lowest elasticity in spite of the relatively high calorie content of meat products. This is because livestock products are an expensive source of calories and are consumed less intensively by calorie-deficient households.

We use growth-linkages to evaluate sectors' economywide impacts (i.e., beyond agriculture). For instance, maize-led growth generates an additional TSh 311 billion (2007 prices) in agricultural GDP and a further TSh 30 billion in nonagricultural GDP. There is an additional 0.10 shilling increase in nonagricultural GDP for every shilling increase in agricultural GDP driven by

Table A1
Sensitivity analysis: poverty- and undernourishment growth elasticities for different foreign and domestic trade elasticities. *Source*: Results from the Tanzania CGE model and poverty/nutrition modules.

	Poverty–growth elasticities (PGE) and rank			Undernourishment–growth elasticities (UGE) and rank		
	Reported results	With lower foreign elasticities	With lower domestic elasticities	Reported results	With lower foreign elasticities	With lower domestic elasticities
Maize-led growth	−1.174 (2)	−1.178 (1)	−1.177 (2)	−1.477 (1)	−1.501 (1)	−1.475 (1)
Sorghum and millet-led growth	−1.136 (4)	−1.119 (4)	−1.156 (3)	−1.348 (3)	−1.360 (2)	−1.368 (2)
Rice and wheat-led growth	−1.100 (7)	−1.090 (7)	−1.101 (7)	−1.148 (5)	−1.135 (5)	−1.164 (5)
Root crops-led growth	−1.182 (1)	−1.177 (2)	−1.188 (1)	−1.350 (2)	−1.350 (3)	−1.352 (3)
Pulses and oilseeds-led growth	−1.141 (3)	−1.142 (3)	−1.128 (4)	−1.161 (4)	−1.200 (4)	−1.184 (4)
Horticulture-led growth	−1.118 (5)	−1.109 (5)	−1.105 (6)	−1.092 (6)	−1.067 (6)	−1.094 (6)
Export crops-led growth	−1.096 (8)	−1.085 (8)	−1.100 (8)	−1.057 (7)	−1.003 (7)	−1.057 (7)
Livestock-led growth	−1.075 (9)	−1.062 (9)	−1.074 (9)	−0.969 (9)	−0.957 (9)	−0.974 (9)
Other agriculture-led growth	−1.113 (6)	−1.100 (6)	−1.112 (5)	−1.022 (8)	−0.971 (8)	−1.023 (8)

maize-led growth (i.e., the average linkage effect for a one unit increase in maize production is 1.10). These nonagricultural spillovers are explained by three factors: first, higher maize production increases raw material supplies and reduces input prices for downstream producers (e.g., grain milling and feedstock); second, since labor is assumed to be fully-employed, increasing agricultural productivity causes some labor to migrate to nonfarm activities; and finally, households' real incomes rise and are then spent partly on nonagricultural commodities.[12]

Total linkage effects for each of the sector-led growth scenarios are shown in Table 6. The highest economywide linkages are in pulses and oilseeds (1.19), livestock (1.18), and sorghum and millet (1.19). However, pulses and oilseeds and sorghum and millet contribute relative little to agricultural GDP (see Table 4), while horticulture, livestock and maize are far more significant contributors.

Multiplying together the initial agricultural GDP share (from Table 4) and the linkage effect (from Table 6) provides a simple indicator of the contribution each unit of additional growth within a sector makes to overall GDP. This indicator appears in the final column of Table 6, and identifies horticulture, livestock and maize as those sectors with the greatest potential to have a meaningful effect on national GDP in Tanzania within the 8 year timeframe of our simulation analysis. Overall, our results show that maize is included in the top three subsectors for all three criteria, suggesting that this crop should be afforded a high priority in the government's agricultural investment plans.

Conclusions

Results from a regional and recursive dynamic CGE model of Tanzania suggest that the current economic growth trend may be overestimated in national accounts and/or that the rate of poverty reduction is underestimated in the household surveys. Nevertheless, the country's weak growth–poverty relationship is also a result of the structure of agricultural growth, which has favored larger-scale production of rice, wheat and traditional export crops in specific geographic locations. Accelerating agricultural growth in a wider range of subsectors than those currently leading the growth process would strengthen the effectiveness of growth at reducing poverty. Faster agricultural growth would also benefit both urban and rural households via increased caloric availability and the ability to pay for food. Reductions in undernourishment are best achieved by improving productivity in the production of key calorie-laden food crops. The staple maize, which is grown extensively by subsistence smallholders, is identified as the key sector for reducing both poverty and undernourishment in Tanzania.

Our modeling analysis focused on how the structure of recent growth has affected poverty and nutrition outcomes. In order to prioritize agricultural subsectors for investment we would also need to consider how to improve agricultural productivity and what the cost might be in terms of investments, extension services or subsidies. This is an area for further research. However, studies for Tanzania and elsewhere identify interventions required to improve smallholders' crop yields, such as investing in rural infrastructure, researching and adopting improved seed varieties, and providing extension services (see Sanchez et al., 2009; Fan et al., 2005; Kilima et al., 2008; Nkonya et al., 1997; Thirtle et al., 2003). In recent years the Tanzanian government has allocated relatively little of its budget to agriculture. However, current development plans indicate a reprioritization of agriculture. Our results indicate that certain food crops, particularly maize, should be afforded central roles within Tanzania's agricultural development plan in order to maximize national growth, poverty and nutritional outcomes.

Appendix A. Sensitivity analysis

As discussed in Section 'Economywide model', the CGE model results may be sensitive to the assumed values of elasticities. Income elasticities in our model were estimated using Tanzanian household survey data. We therefore focus our sensitivity analysis on trade elasticities. Foreign trade elasticities were drawn from cross-country estimates and determine the ease at which consumers and producers can shift between domestically produced and foreign goods. The foreign tradability of a crop will determine the extent to which domestic prices change in response to increased production levels. Our domestic trade elasticities were assumed to be high for all agricultural commodities, implying that goods can readily be supplied across regions via national markets. In the following sensitivity analyses we halve foreign (import and export) and domestic trade elasticities, thereby reflecting a more constrained trading environment. Table A1 shows PGEs and UGEs under alternative trade elasticities.

As expected, the PGEs are typically lower than the reported results when foreign trade elasticities are halved, since larger declines in domestic prices offset farm income gains. This is especially true for export-crop-led growth, where domestic demand is particularly limited. An exception is maize, where the benefit to nonfarm consumers of lower domestic prices offsets lower

[12] Since factors are fully-employed in our model, we refer to "linkage effects" rather than "multiplier effects".

Table A2
Sensitivity analysis: undernourishment growth elasticities for different calorie lines.
Source: Results from the Tanzania CGE model and poverty/nutrition modules.

	2550 kcal/day	1740 kcal/day
Maize-led growth	−1.174 (2)	−1.178 (1)
Sorghum and millet-led growth	−1.136 (4)	−1.119 (4)
Rice and wheat-led growth	−1.100 (7)	−1.090 (7)
Root crops-led growth	−1.182 (1)	−1.177 (2)
Pulses and oilseeds-led growth	−1.141 (3)	−1.142 (3)
Horticulture-led growth	−1.118 (5)	−1.109 (5)
Export crops-led growth	−1.096 (8)	−1.085 (8)
Livestock-led growth	−1.075 (9)	−1.062 (9)
Other agriculture-led growth	−1.113 (6)	−1.100 (6)

incomes for maize farmers. Our conclusions are thus robust to changes in foreign trade elasticities (i.e., the ranking of sector-led growth scenarios remains unchanged). Reducing domestic trade elasticities has no effect on export crops' PGEs, but has larger implications for food crops. Changes in rankings are small and our conclusion that maize growth is important for poverty reduction remains unchanged. The same is true for UGEs.

The reported calorie-deficiency rates and UGEs are based on Tanzania's official calorie line of 2550 kcal per male adult equivalent per day. However, the Food and Agriculture Organization (FAO) recommends a calorie line of 1740 kcal/day for this country. Hence, Table A2 compares UGEs for the two calorie lines. Maize's UGE increases marginally as we move to the lower calorie line, whereas the other elasticities decline marginally. This reflects slight changes in households' consumption preferences around the lower calorie line, with maize as the least expensive source of calories becoming a more important part of the diet. Changes in the rankings are small, and so our results are robust to using alternative calorie lines.

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