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July 2005

DSGD Discussion Paper No. 20

Growth Options and Poverty Reduction in Ethiopia

A Spatial, Economywide Model Analysis for 2004-15

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with Madhur Gautam, James Keough, Jordan Chamberlin, Liangzhi You, Detlev Puetz, Danielle Resnick and Bingxin Yu

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ACKNOWLEDGMENTS

The authors gratefully acknowledge financial support from the United States Agency for International Development (USAID), the World Bank, and the U.K. Department for International Development (DFID) for the collaborative research project on Ethiopian agricultural growth and poverty reduction. They also thank Peter Hazell for guidance and suggestions in the research process, Eleni Gabre-Madhin and John Pender for suggestions and comments throughout the research process, Lisa Smith for sharing her work on the Household Income, Consumption, and Expenditure Survey (HICES), seminar participants in both Addis Ababa and Washington, D.C., and Mary Jane Banks for editing the English version of the paper.

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ABSTRACT

This study assesses which agricultural subsectors have the strongest capacity to drive economic growth and poverty reduction in Ethiopia, and what kind of agricultural and nonagricultural growth is needed to achieve the millennium development goal of halving the 1990 poverty rate by 2015. A spatially disaggregated, economywide model was developed under the study, enabling the analysis of growth and poverty reduction linkages at national and regional levels using national household surveys, agricultural sample surveys, geographic information systems, and other national and regional data.

The study reveals that agriculture has the potential to play a central role in decreasing poverty and increasing growth in Ethiopia, primarily through growth in staple crops and livestock. Agricultural growth also requires concurrent investments in roads and other market conditions. At the subnational level, similar rates of agricultural growth have different effects on poverty, necessitating regionally based strategies for growth and poverty reduction.

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1. INTRODUCTION

With a per capita income of only about 20 percent of the African average, Ethiopia is one of the world's poorest countries. In addition, persistent food crises have left a significant proportion of the population food insecure. These circumstances reflect accumulated challenges from past decades. In particular, Ethiopia has experienced seven major droughts since the early 1980s, five of which resulted in famine. The most recent drought of 2002/03 affected approximately 30 million people (EM-DAT 2004). Despite significant food-aid, little progress has been made in surmounting this situation.

In addition to climatic factors, Ethiopia suffered from misguided economic policies under the socialist Dergue regime, which ruled from 1974 until 1991. When the Ethiopia Peoples' Revolutionary Democratic Front (EPRDF) replaced the Dergue regime in 1991, a number of market-oriented reforms were implemented, some aimed at stimulating agricultural and rural growth (World Bank 2004). For example, the country liberalized its foreign exchange markets and dramatically decentralized public administration to the *woreda* (district) level. In rural areas, grain markets were liberalized

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and fertilizer markets opened up to participation from the private sector. In 1992, the Government of Ethiopia also established the agricultural development-led industrialization (ADLI) strategy, which emphasized the role of the agricultural sector as a catalyst for immediate food security improvement and long-term, broad economic growth.

The outbreak of conflict with Eritrea between 1998 and 2000, however, created a humanitarian emergency in the north of the country and reduced the availability of resources to finance many of these reforms. During this time, not only did increases in official defense spending significantly reduce funding to other sectors, especially for antipoverty programs, but donors and investors also reduced their support (World Bank 2004).

With the return to peace, the Government of Ethiopia reaffirmed its commitment to generating growth and reducing poverty, especially through a strong focus on the rural sector, particularly agriculture. More than 85 percent of the country's population live in rural areas, where agriculture is the main economic activity and where the poverty ratio is particularly high; hence, any strategy for slashing Ethiopia's poverty and hunger must focus on generating rapid growth in the agricultural sector. To this end, the government not only continued to support ADLI strategy but also launched a series of development and poverty reduction programs, including the Sustainable Development and Poverty Reduction Program (SDPRP [2001]), Agricultural Growth and Rural Development Strategy and Programs (2004), and the Food Security Program (2004). Agricultural growth, food security, and accelerated rural development are fundamental to all of these endeavors.

In order to identify the kinds of investments that have the greatest impact on agricultural growth, in turn driving broader growth and poverty reduction, a deeper understanding of the linkages between agriculture, economic growth, and poverty reduction is needed. This study was therefore undertaken to develop a spatially disaggregated, economywide model to enable analysis of growth and poverty reduction linkages at national and regional levels. Data for the model were drawn from recent national household surveys, national agricultural sample surveys, and geographic information systems (GIS), among other national and regional data.

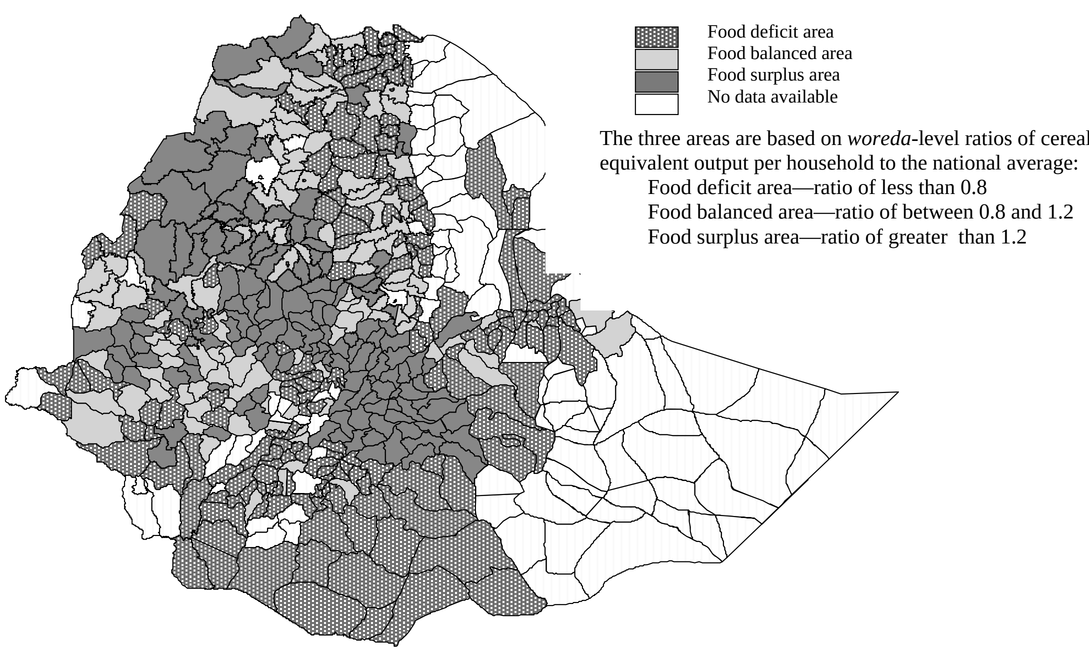
Results from the study indicate that broad-based agricultural growth is the key means by which Ethiopia can halve its incidence of poverty by 2015. More specifically, within the agricultural sector, growth in staple crops and livestock should be given priority because of their superior capacity to contribute to poverty reduction. Increasing national staple food availability by 50 percent by 2015 would significantly help to reduce poverty in Ethiopia; achieving this goal, however, depends on reducing the productivity gap between the range of traditional and modern technologies adopted in the country to date. Achieving sustainable agricultural growth will also require supporting investments in roads and other market conditions.

The study also emphasizes the need for regionally differentiated strategies in response to both the country's size and its heterogeneous natural resource and economic environments. More than 50 percent of the country's poor people live in the food deficit area, where the staple food availability per household is half the national average level. Given the extreme nature of the poverty and food security challenge in these areas, however, growth in staple foods alone would not be a sufficient remedy. A balanced agricultural growth strategy providing both increased food availability and income levels appears to be a viable option. However, market development and access should be integral to this strategy, given that more than 50 percent of food staples are currently derived from food surplus areas where food staples availability per household is 70 percent higher than the national average.

II. AREAS OF FOOD DEFICIT, FOOD BALANCE AND FOOD SURPLUS

As indicated in the introduction, food security is the central issue of Ethiopian agricultural growth and poverty reduction. For this reason, in the context of this study, the country is examined according to sources of domestic food availability, resulting in its division into three categories: areas of food deficit, food balance, and food surplus (Figure 1). Based on data from Ethiopia's 2001/02 Agricultural Census, *woredas* in which the average cereal equivalent output per rural household is 20 percent below the national average fall into the food deficit area, those with output between 80 and 120 percent of the national average form the food balanced area, and those with output 20 percent or more above than national average constitute the food surplus area.[1]

Figure 1. Food Deficit, Food Balanced, and Food Surplus Areas



Source: Constructed by authors based on Democratic Republic of Ethiopia (2002).

[1] The study includes 460 *woredas*. Cereal output equivalents were used to represent food availability. Equivalents include cereals, pulses, oil crops, and root crops, and account for over 60 percent of household food consumption in the urban and 70 percent in rural areas. The conversion ratio for crops other than cereals was based on their calorie content (see the FAOSTAT web site).

Twenty-six million Ethiopians live in the food deficit area, where the annual food availability averages only about 530 kilograms per household, even in good years.[2] This represents half the national average (Table 1). In contrast, food availability per household in the food surplus area averages 1,800 kilograms, which is 70 percent above the national average. The high proportion of cereals and other staple crops in the food availability calculation (more than 70 percent of rural household food consumption) is indicative of extremely low food availability and alarming food insecurity, in turn a reflection of very low income levels per capita and a very high rate of poverty. Compared with a 2000 rural poverty rate of 46 percent nationwide,[3] the poverty rate in the food deficit area is 60 percent; in the food surplus area it is less than 40 percent. Fifty percent of the rural poor now live in the food deficit area; that area, however, only accounts for 37 percent of the total rural population.

Table 1. Population and Poverty Rates in the Three Areas

Indicator	Food deficit area[a]	Food balanced area[b]	Food surplus area[c]	National level
Total population	25.6	22.1	22.3	70.0
Rural	21.9	19.7	17.2	58.9
Urban	3.7	2.4	5.0	11.1
Share of population				
Rural	37.3	33.4	29.3	100.0
Urban	33.0	21.7	45.3	100.0
Share of poor people				
Rural	49.1	25.8	25.1	100.0
Urban	20.3	29.1	50.6	100.0
Poverty rate				
Rural	60.5	35.4	39.0	45.8
Urban	22.6	49.2	41.0	37.0

Source: Calculated by authors from Federal Democratic Republic of Ethiopia (2002).
[a]*Woredas* with cereal equivalent output per rural household at levels 20 percent below the national average.
[b]*Woredas* with cereal equivalent output per rural household at levels of 80–120 percent of national average.
[c]*Woredas* with cereal equivalent output per rural household at levels 20 percent higher than the national average.

[2] The calculation is based on data for 2001/02, which was a good harvest year for most of the country.
[3] The poverty rate used in this study is consistent with data from HICES 1999/2000.

A major constraint to meeting food demand for the majority of rural households in the food deficit area is extremely small farmland area. National farm size, including permanent and temporal crops, averages about one hectare. In the food deficit area, however, farm size averages only 0.57 hectare compared with 1.38 hectares in the food surplus area. (Table 2). Of the 184 *woredas* constituting the food deficit area, per household farmland is less than 0.4 hectares in half of them, and less than 0.3 hectares in one-third of them. Cereal production yields are also lower than the national average, further eroding food security in these areas. The average cereal yield in the food deficit area is about one metric ton per hectare, 20 percent below the national average and 30 percent below yields in the food surplus area. (Table 3). Even taking other staple crops into account, a significant yield gap in staple crop production still exists between the food deficit and food surplus areas.

Table 2. Land Size and Cereal Output per Household in the Three Areas

***Woreda*-level rural household average**	**Food deficit area**	**Food balanced area**	**Food surplus area**	**National level**
Cereal land holding (hectares per household)	0.41	0.74	1.07	0.70
Farmland holding (hectares per household)	0.57	0.94	1.38	0.90
Cereal output (kilograms per household)	418	883	1,579	904
Cereal equivalent output (kilograms per household)	534	1,078	1,814	1,079

Source: Calculated by authors from Federal Democratic Republic of Ethiopia (2002).

Table 3. Cereal Yield and Input Use in the Three Areas

Indicator	**Food deficit area**	**Food balanced area**	**Food surplus area**	**National level**
Total cereal equivalent yield (tons per hectare)	1.14	1.15	1.32	1.22
Cereal yield without modern input (tons per hectare)	0.96	1.11	1.32	1.14
Cereal yield using fertilizer only (tons per hectare)	1.24	1.25	1.44	1.36
Cereal yield using fertilizer and improved seed (tons per hectare)	1.65	2.20	2.63	2.46
Fertilizer use rate in cereals (percent)	29.12	26.40	56.13	40.21
Fertilizer combined with seed rate (percent)	3.08	3.15	4.88	3.91

Source: Calculated by authors from Federal Democratic Republic of Ethiopia (2002).

Given a high population density in most of Ethiopia's rural areas, increasing land productivity is the only feasible strategy for improving food security. The intensity of labor use and other inputs is often linked to population pressure (Boserup 1965), a reality also reflected in international trends. Fewer modern inputs are used in the food deficit area than in the food surplus area. For example, only 29 percent of cereal land is fertilized in the food deficit area compared with a national average of about 40 percent and a food surplus area rate of 56 percent. Returns to modern inputs, in terms of yield increases, are also low in the food deficit area compared with those in the surplus area. (Table 3).

Certain agroecological conditions, such as soil moisture, affect the feasibility and efficiency of fertilizer use. Using the growth period as an indicator of agroclimatic conditions, *woredas* were spatially grouped according to two agricultural domains: high agricultural potential with a maximum growth period of more than six months, and low agricultural potential with a maximum growth period of less than six months. Surprisingly, 70 percent of *woredas* and 80 percent of rural households in the food deficit area were classified as having high agricultural potential; this compared with 90 percent of both *woredas* and rural households in the food surplus area. There is no significant difference in the ratio of fertilized cereal area to total area in the two domains within the food deficit or food surplus areas. An econometric test further proves that differences in the agricultural potential cannot explain the difference in fertilizer use or the cereal yield gap between these areas.

Given the absence of household-level data, further analysis of factors affecting production decisions by farmers, including input use, were not possible.[4] Nevertheless, findings from *woreda*-level data indicate a significant yield gap and, thus, potential for improving land productivity in those areas dealing with severe food insecurity.

[4] The Agricultural Census data were aggregated to the *woreda* level.

III. CHALLENGES TO ETHIOPIAN AGRICULTURE: "BUSINESS AS USUAL" DOES NOT WORK

The Model Description

In order, first, to demonstrate the necessity for increased agricultural growth in Ethiopia, an economywide model was developed to analyze the impact of Ethiopia's current growth trajectory on poverty, were it to perpetuate—the so called business-as-usual scenario (also known as the "baseline"). To simulate the country's economic structure, 34 disaggregated agricultural commodities and two aggregated nonagricultural sectors were incorporated into the model (see Appendix A for a list of agricultural commodities/sectors included in the model.) Production and consumption of all 36 commodities (or groups of commodities) were further disaggregated into 56 spatial zones. The supply function is defined at the zonal level and depends on output prices and a productivity parameter; for crops, it is further identified as a yield and an area function. While the land constraint is not explicitly simulated, the model imposes a constraint on price elasticities in crop supply functions to avoid a simultaneous increase in the area across all crops in a given year. Area expansion in maize production, for example, necessarily results in a reduction in growing area for one or more other crops, such as wheat.

The production of major staple crops and livestock products involves a variety of technologies. For staple crops, modern inputs and their effects on crop productivity are captured through the identification of 15 different technologies, maize production, for example, incorporates four primary modern inputs—fertilizer, improved seeds, pesticide, and irrigation (individually or jointly)—and also includes production without modern inputs. While the model captures the average difference in crop yields across technologies, the marginal effect of increased use of an input for a given technology is not captured because input uses are not explicitly included in the supply function. The yield gaps for a specific crop among the 15 technologies are defined at the zonal level and are consistent, by zone, with data from the national agricultural sample surveys for

1997 and 2000. Data on irrigation was available for cash crop production and hence was employed in supply functions for those crops.

For livestock, the model captures the productivity difference between traditional and modern technologies. For example, three types of cattle are raised to produce beef: draught animals, from which beef is a byproduct; beef animals, using traditional technology; and beef stock, using improved technology. The productivity (yield) gaps resulting from the use of different types of technologies in animal production are reflected in the supply function. Moreover, the supply function also captures the difference in feed use between traditional and modern technologies. Livestock production under modern technology requires feedgrain, while under traditional production it assumes feeding via grazing only. The feedgrain demand function is therefore defined only for improved technology, and is a function of grain crop prices. Different technologies are similarly defined for dairy, poultry, and sheep and goats.

The demand function is also disaggregated to the zonal level and depends on prices and per capita (rural or urban) income. Data used to determine the demand function are derived from the 1999/2000 Household Income, Consumption, and Expenditure Survey (HICES [CSA 2000]). The demand function satisfies the budget constraint by imposing a homogeneous condition on the elasticities, meaning that total expenditure on commodities equals rural or urban income at the zonal level. Total zonal-level income is determined endogenously and is equal to zonal-level total production revenues for both agriculture and nonagriculture. Since intermediate inputs and their prices are not explicitly modeled, agricultural revenue is adjusted to represent agricultural GDP (henceforth, AgGDP) by reducing price levels. Together with the two nonagricultural sectors, which represent manufacturing and other nonagricultural activities, total income equals GDP at the national level.

An integrated national market is assumed, with different price levels across zones. The difference between a zonal-level price and a national market price (represented by the market price in Addis Ababa) is defined according to marketing margins. For a commodity produced in a food surplus zone, its producer price is lower than the Addis

Ababa market price; similarly, for the same commodity produced in a food deficit zone, its consumer price is higher than the Addis Ababa price. National market prices for most commodities are endogenously determined by national-level supply and demand, as are zonal-level prices.

The model also considers price linkages between domestic and international markets. Import parity prices are defined as border prices, plus transportation and other marketing costs from the port to Addis Ababa; export parity prices are the border prices minus transportation and marketing costs. Both import and export prices are exogenous in the model, but they can affect trade for a specific commodity. For example, if endogenously determined domestic prices for some commodities rise due to increased shortages in availability and increased prices eventually converge with import parity prices, imports occur. Similarly, if the domestic prices decline over time to the level of the export parity prices, exports occur. Once international trade arises, prices for the traded commodities equalize either with import or export prices.

The household-level data from HICES is linked with zonal-level per capita income in order to calculate average poverty rates at the regional or national level. Given zonal-level income distribution, poverty shares per household group—represented by the sample households and weighted by the sample size, also taking household size into account—are constant and linked to total zonal-level (rural or urban) income, which is endogenously solved in the model. The poverty line, defined in terms of real income, is constant but differs for rural and urban areas. The share of population defined as poor changes with zonal-level per capita income, which is solved from the model such that new poverty rates can be obtained when both income and population grow (noting that population grows exogenously in the model.) Detailed mathematical descriptions of the model are presented in Appendix B.

Stagnant Agricultural Growth Results in Higher Poverty

The analysis of the business-as-usual growth path is based on average agricultural and nonagricultural growth trends for 1995–2002, during which time about 90 percent of total crop production increases and 70 percent of cereal production increases resulted from area expansion. Over the same period, the cereal production growth rate was below 2 percent per year—lower than the 2.5 percent population growth rate—and the growth rates of total crop and cereal yields were about 0.2 and 0.6 percent per year, respectively. Under the business-as-usual scenario to 2015, and based on livestock production growth of 4.2 percent per year and nonagricultural growth of 3.8 percent per year, GDP is projected to increase at 3.1 percent per year, and AgGDP at 2.5 percent per year.

Table 4. "Business as Usual" Won't Work: Baseline Simulation Results

A. Growth trends[a]	Gross domestic product (GDP)	Agricultural gross domestic product (AgGDP)	Nonagricultural gross domestic product (NonagGDP)
Annual growth rate	3.1	2.5	3.7
Within agriculture	Cereals	Cash crops	Livestock
Production growth	2.0	4.6	4.2

B. Baseline simulation results	Base year[b]	2015 projections
Food availability (per capita cereal equivalent output in kilograms)	195	182
Average cereal yield (tons per hectare)	1.28	1.38
Total poverty rate (percent)	44.4	45.7
Population under poverty line (millions)	29.2	40.6
Calories per capita per day	1,834	1,715
Rate of malnourished children (percent)	47.0	49.5

Source: IFPRI model simulation results for Ethiopia, 2005.
[a] *Annual average during 1995–2002.*
[b] *2003.*

On this basis, the livelihood of the majority of Ethiopians will not improve by 2015. Without changes in the country's current economic environment, growth in agriculture—and especially in cereal production—will contract compared with population growth and the national poverty rate will rise (the model forecasts an increase from the high 2003 level of 44.4 percent to 45.7 percent by 2015). Given 2.5 percent yearly population growth during 2003–15, the number of people living below the poverty line is estimated to increase to 41 million by 2015, an increase of 10 million people. Under these conditions, the majority of the country's poor people will continue to struggle to meet their most basic needs, as represented by average caloric intake, per capita per day, which is projected to remain relatively unchanged in 2015 under the business-as-usual scenario (Table 4).

Under this baseline scenario, poverty will mainly increase in the food deficit area. At the national level, analysis of the rural poverty dynamics shows that more than 97 percent of population who were poor in 2003 will likely remain poor in 2015. At the regional level, however, almost all those in the food deficit area who were poor in 2003 will remain poor in 2015; those people who do manage to move out the poverty will come from the food surplus area. Moreover, at the national level, 6 percent of people who were not poor by 2003 standards will fall into the poverty by 2015; the comparable percentage in the food deficit area is 7 percent. Consequently, under the business-as-usual scenario, the poverty rate further increases in the food deficit area, from the 2003 rate of 60.5 percent to 64.4 percent by 2015 (Table 5).

Table 5. Baseline Rural Poverty Dynamics

Indicator	Food deficit area	Food balanced area	Food surplus area	National level
Rural population				
2003 (millions)	21	19	16	56
2015 (millions)	28	25	22	75
Poor population				
2003 (millions)	12	7	6	25
2015 (millions)	17	10	8	35
Poverty rate				
2003 (percent)	60.5	35.4	39.0	45.8
2015 (percent)	64.4	39.1	37.3	48.0
Poor by 2015 (share of poor in 2003)	99.7	98.3	92.0	97.4
Nonpoor by 2015 (share of poor in 2003)	0.3	1.7	8.0	2.6
Still not poor by 2015 (share of nonpoor in 2003)	93.0	95.4	97.0	93.8
Falling into poor by 2015 (share of nonpoor in 2003)	7.0	4.6	3.0	6.2

Source: IFPRI model simulation results for Ethiopia, 2005.
Note: Data were calculated from the baseline simulation results.

Climate Risk Further Deteriorates Rural Income and Agricultural Growth

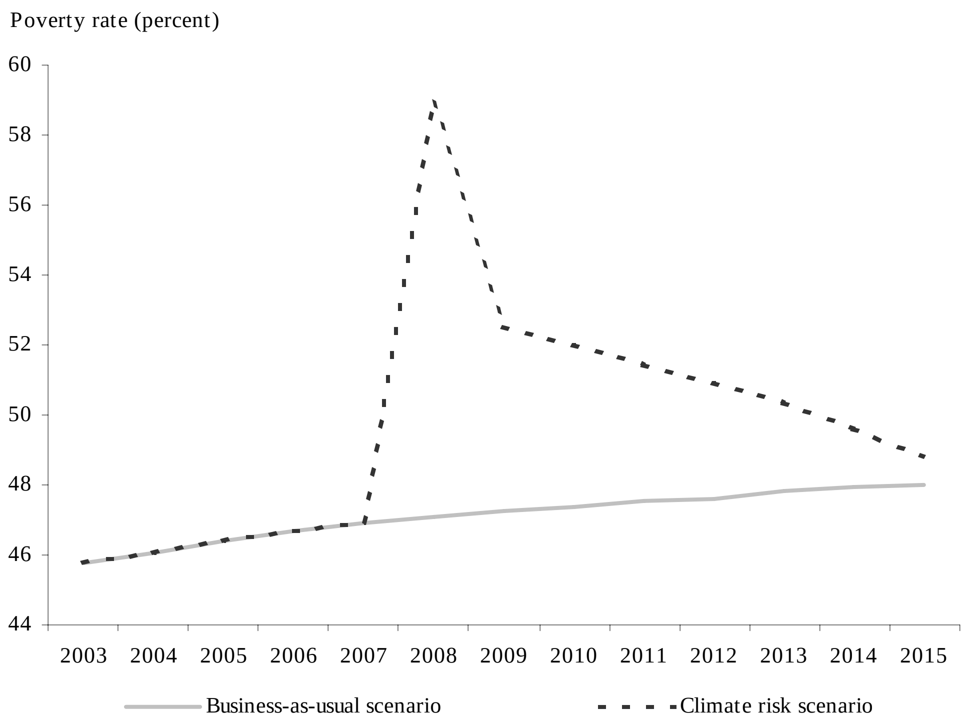
The business-as-usual scenario is based on a smoothed growth trend from 1995 to 2002. Smoothed agricultural growth rates mask production variability associated with water availability. In reality, Ethiopia experiences significant shocks in water availability, and a high correlation exists between drought and agricultural performance (Easterly 2002). A sluggish growth pattern in agriculture, captured by the time trend (and assumed in the business-as-usual scenario), is mainly due to declines in agriculture in years of bad weather, despite growth in other years. The climate risk scenario was therefore designed to test whether a smoothed time trend in agriculture might not fully capture the negative effects of drought on agricultural performance and poverty, given that poor people are extremely vulnerable to weather-related risk.

This scenario is similar to the business-as-usual scenario in all respects, with the exception that a drought is simulated during the period of analysis. The drought is modeled using climate data to determine average rainfall conditions, by spatial location and month. Rainfall deviations from the mean value are then estimated for each year, also by location and month. The calculated rainfall deviation data show a clear spatial and temporal pattern for the droughts over the past century. The 1997/98 drought, the most recent characteristic drought for which adequate data were available, was chosen as the basis for rainfall deviations across zones. The shortage in rainfall and its effect on the economy are modeled as an exogenous shock to crop yield and area in 2008. The degree of the shock varies across zones as a consequence both of rainfall deviations and the ratio of irrigated and rainfed areas. The model also assumes that drought affects the nonagricultural sector and the livestock subsector, but to a lesser extent.

After the drought year, it is assumed that cultivated areas begin to recover and yield growth rates rise from 2009, such that by the end of 2015 the value of agricultural production is roughly the same in both the business-as-usual and climate risk scenarios. The quantity of cereal production under the business-as-usual scenario, however, is still lower than under the climate change scenario, implying that grain prices are higher after the drought than they would be otherwise.

The rural poverty rate rises significantly in the year of the drought (Figure 2), although growth in subsequent years causes the poverty rate to fall from its 2008 peak such that, by 2015, it closely converges with the 2015 rate under the business-as-usual scenario. A significantly higher poverty rate in drought years reflects the vulnerability of poor people given the severity of this additional shock. Similar shocks can result from other natural disasters, family illness, or from livestock disease. While the model cannot fully capture the effects of external shocks on Ethiopia's poor, the climate risk scenario emphasizes their extreme vulnerability in the absence of additional agricultural growth.

Figure 2. Rural Poverty Rate Under Business-as-Usual and Climate Risk Scenarios



Source: IFPRI model simulation results for Ethiopia, 2005.
Note: The only difference between the two scenarios is the occurrence of a drought in 2008.

IV. GROWTH OPTIONS AMONG AGRICULTURAL SUBSECTORS AND THE EFFECT ON POVERTY REDUCTION

The Model Assumptions in the Simulations

As established, the business-as-usual scenario shows that stagnant growth in Ethiopia's agricultural sector will only allow further deterioration of the country's food security. Hence, without additional growth in agriculture, it will be impossible to meet the goal of halving the incidence of poverty rate by 2015. Considering that most of the population relies on agriculture for its livelihood, any strategy for slashing hunger and poverty in Ethiopia must focus on generating rapid agricultural growth.

Nevertheless, achieving the objectives of halving hunger and poverty requires a greater understanding of which agricultural subsectors can best drive growth and slash poverty. The degree to which agricultural subsectors contribute to growth and poverty reduction will differ. Hence, this section focuses on an evaluation of four agricultural subsectors—staple crops, livestock, traditional exportables (coffee), and nontraditional exportables (selected fruits and vegetables, cotton, chat,[5] sesame seed, and sugar, and other horticultural products)—in terms of the country's growth and poverty reduction strategy, assessing their contribution by exogenously increasing the productivity growth rate of one subsector, while maintaining the growth of the other two at their baseline levels.

Assuming similar growth rates at the subsector level, greater economywide growth will be generated by the larger subsectors, in turn producing a (generally) larger effect on poverty. On the other hand, small subsectors have greater capacity to grow rapidly and require the investment of fewer resources to do so. Thus, in determining whether a subsector will ultimately drive growth, both the linkage effects on the economy and poverty as well as the growth potential (determined by supply and demand factors) must be considered. In order to ensure comparable quantitative measurement across the agricultural subsectors modeled, those exhibiting similar AgGDP growth but different

[5] Fresh leaves of a stimulant tree crop exported to Arabic countries.

productivity growth were targeted to assess the growth effect of each on overall economic growth and poverty reduction.

Staple crops include cereals, root crops, pulses, and oil crops, and represent the largest agricultural subsector in terms of value-added (65 percent), while the livestock sector is the second-largest, accounting for 26 percent of agricultural value-added. While the two export subsectors constitute quite small shares (about 5 percent of agricultural value-added each), they were included in the simulations because of their growth-promoting potential.

The simulated additional annual growth for staple crop productivity was first determined, at 1.5 percent, which implies 2.1 percent annual growth in yields (the comparable baseline productivity growth rate is 0.6 percent based on actual data from 1995–2002). Taking into account the size of each agricultural subsector, simulated productivity growth rates were then determined: 3.4 percent for livestock and 13 percent for both traditional and nontraditional exportables.

Growth in Staples is the Priority for Poverty Reduction

Unsurprisingly, cereals and other staple crops are the most important income source for the majority of small farmers. Thus, this subsector should have strong potential to substantially alleviate rural poverty. Indeed, model results under the staple crop growth scenario indicate the capacity for 3.4 percent growth per year from 2004 to 2015 on the basis of a 2.1 percent average yearly yield growth combined with the 1.3 percent crop area expansion already assumed under the business-as-usual scenario. Taking supply–demand, agricultural–nonagricultural, and cross-sectoral linkages in agriculture into account, staple crop growth of this order (combined with assumed baseline growth in the other agricultural/nonagricultural subsectors) results in GDP growth of 3.9 percent per year, and AgGDP growth of 3.5 percent per year. This compares with business-as-usual rates of 3.1 and 2.5 percent, respectively (Table 6, column 2).

Table 6. Growth and Poverty Reduction Outcomes under Different Agricultural Sector Growth Options

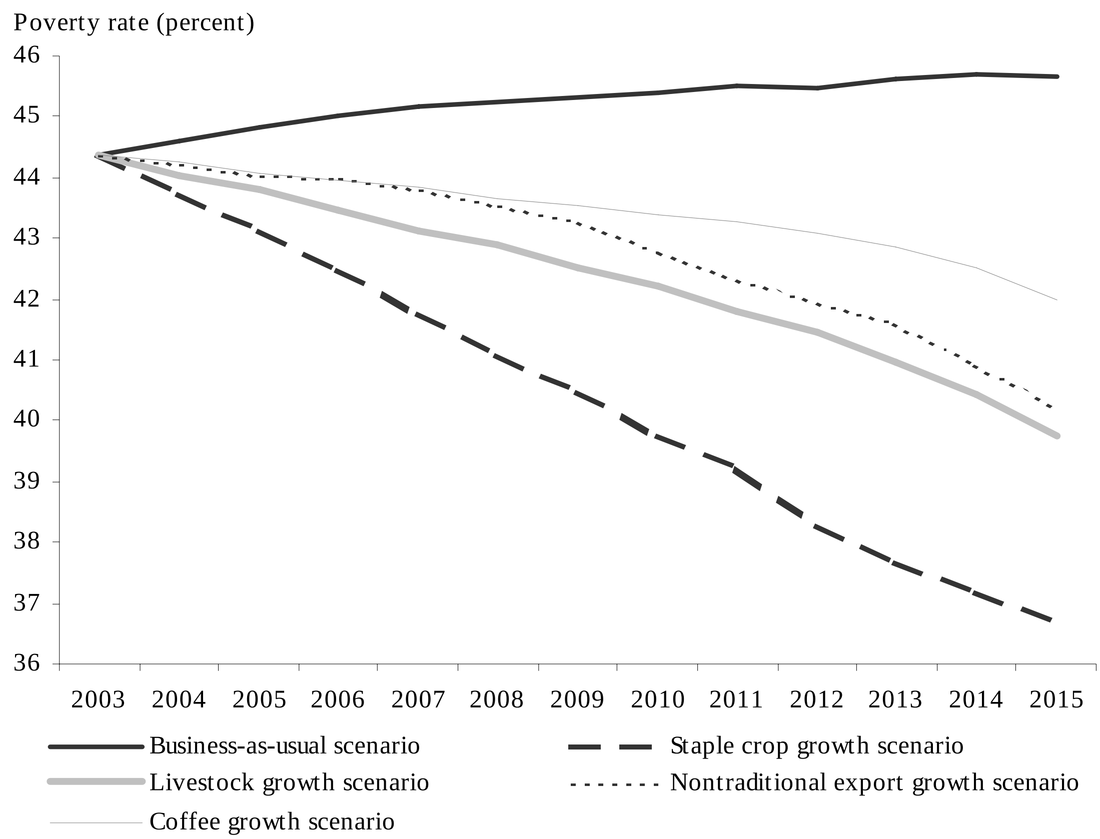
Indicator	Base year	Staple crops only[a] (1)	Livestock only[b] (2)	Nontraditional Exportables only[c] (3)	Coffee only[d] (4)
GDP growth rate (percent)	3.1	3.9	3.9	3.6	3.6
Ag GDP growth rate (percent)	2.5	3.5	3.5	3.4	3.4
Calories per person per day by 2015 (baseline = 1,834)	1,715	1,963	1,806	1,784	1,731
Poverty rate by 2015 (baseline = 44.4)	45.7	36.7	39.7	40.2	42.0

Source: IFPRI model simulation results for Ethiopia, 2005.
Note: The base year is 2003; growth rates are for the period 2004–15.
[a]*An additional 1.5 percent annual productivity growth over baseline levels.*
[b]*An additional 3.4 percent annual productivity growth over baseline levels.*
[c]*An additional 9 percent annual productivity growth over baseline levels.*
[d]*An additional 11 percent annual productivity growth over baseline levels.*

Model results show that a 1.5 percent annual growth in staple crops over baseline levels would stimulate GDP and AgGDP growth and, in turn, could significantly reduce poverty in Ethiopia. The contribution of staple crop growth to poverty reduction is greater than growth options in any other agricultural or nonagricultural sector modeled (Figure 3), though it is possible that growth in other sectors could result in a similar growth effect on the overall economy. Small farmers directly benefit from improved staple crop productivity. In the model, such growth causes the rural poverty rate to fall to 37.7 percent—more than 10 percentage points below the poverty rate for the same year under the business-as-usual scenario, and 8 percentage points below the 2003 rural poverty rate. Staple crops are the most important source of food energy for both rural and urban poor consumers. Ethiopian national household survey data indicate that poor people in rural areas whose income is below the poverty line spend about 70 percent of their total income on staple food crops; this is 30 percent higher than the rural average. In contrast, comparable urban households spend almost 50 percent of their income on staple food crops, which is 65 percent higher than the urban average. Raising productivity in staple crops has the effect of lowering food prices, given increased supply, enabling the urban poor to pay less and consume more.

Consequently, in the model, the urban poverty rate falls to 31 percent by 2015, 5.7 percent below the 2003 level.

Figure 3. National Poverty Rate Under Four Agricultural Subsector Growth Scenarios



Source: IFPRI model simulation results for Ethiopia, 2005.
***N**ote: Scenarios reflect comparable 3.4–3.5 percent AgGDP growth per year.*

Combining Staple Crop and Livestock Growth to Maximize the Poverty Alleviation Effect

Actual growth in the livestock sector during 1995–2002, at 4.2 percent per year, was higher than comparable growth in staple crops or agriculture as a whole, which implies the capacity for strong future growth. The additional 3.4 percent annual growth modeled under the livestock growth scenario results in annual productivity growth of 7.6 percent (assuming growth in the other agricultural and nonagricultural sectors remains constant at baseline levels. The results also show that livestock sector growth of this magnitude could induce similar GDP and AgGDP growth to that modeled for staple crops. Nevertheless, under the simulations, the ultimate effect of such livestock sector growth has a comparatively smaller effect on poverty, which falls to 39.7 percent in 2015, driven by livestock sector growth, compared with 36.7 percent, driven by staple crop sector growth. (Table 6, column 3).

There are both production- and consumption-side explanations as to why livestock growth has a weaker poverty reduction impact. A key factor is the comparatively smaller share of poor farmer income derived from the livestock subsector compared with the staple crop subsector. On the consumption side, both the rural and urban poor consume far fewer livestock products. Based on household survey data, rural households living below the poverty line spend less than 4 percent of their income on livestock and dairy products, which is 40 percent less than an average rural household would spend. In poor urban households, expenditure on livestock and dairy products represents about 3 percent of household income, which is 55 percent less that the average urban household would spend. Consequently, poor consumers in both rural and urban areas benefit less from the lower prices of livestock products that increased production induces.

Given linkage effects across sectors, a greater poverty-reduction effect results in rural areas from a combination of both staple crop and livestock subsector growth. With this combination, simulation results indicate a drop in rural poverty from 45.8 percent in 2003 to 33 percent in 2015. The linkage effect is particularly strong in the food deficit area, where the poverty rate falls from its high 2003 level of 60.5 percent to 49.6 percent in 2015. Under the two separate scenarios where only staple crops or livestock grows, poverty in the food deficit area only drops to 56.6 and 58.1 percent, respectively, in 2015.

Growth in Export Crops Plays a Limited Role

As already mentioned, traditional and nontraditional exports account for about 5 percent of AgGDP each. Actual production in nontraditional exportables grew rapidly during 1995–2002, at about 4.6 percent. In contrast, growth in coffee exports stagnated over the same timeframe, although coffee still ranks as Ethiopia's most important exportable crop. In the two export growth scenarios, output of both traditional and nontraditional exportables is assumed to grow by 13 percent—an additional 8.4 and 11.2 percent, respectively, above their average yearly levels during 1995–2002. As discussed above, these rates were determined to be quantitatively comparable with those delineated for the staple crop and livestock subsectors (1.5 and 3.4 percent growth over baseline levels, respectively). Achieving 1 percent annual growth in the production of nontraditional exportables requires much higher growth in actual exports—as much as 29 percent per year over the simulation period. In the absence of possible market constraints, export subsector growth of this magnitude could induce overall economic growth of 3.6 percent per year, and agricultural growth of 3.4 percent per year. Nevertheless, the overall contribution of this growth to poverty reduction is relatively small. The poverty rate only falls 4.2 percentage points below baseline levels, to 40.2 percent (Table 6, column 4). Additional growth in coffee exports has a similar modest poverty reduction effect in the model simulations.

The most likely explanation for these modest impacts is that farmers who grow exportables are usually concentrated in particular regions, such as around cities, largely in response to technological and financial constraints. Poor farmers are, more often than not, unable to adopt the necessary technologies without significant extension support, and the initial investments required for such commercial production are prohibitive. On the demand side, increased agricultural export production, by definition, provides little benefit to poor consumers in both rural and urban areas. However, the goal in promoting growth in this subsector is not direct benefits to poor people through the commodities themselves but rather benefits stemming from the resulting economic growth (in terms of income and employment, for example). This being the case, the most important constraint to growth in agricultural exportables—and therefore economic growth and poverty reduction outcomes—is lack of market access.

As mentioned above, 13 percent annual growth in the production of nontraditional export commodities and coffee implies much higher growth of actual exports (as much as 29 percent for nontraditional exports per year). But if transportation infrastructure and other market conditions can't support this growth, the desired linkage effects on the broader economy and poverty will be thwarted. Consequently, if the agricultural exports subsector is to make a significant contribution to economic growth and poverty reduction, it must be accompanied by reduced market transaction costs and greater investment in transportation.

A Multi-sector Growth Strategy Has the Greatest Poverty-Reducing Effect

The above analysis focuses on individual agricultural subsectors to emphasize the different effect each has on poverty reduction. Obviously growth in any one subsector would not produce the necessary linkage effects to fulfill MDGs. While growth in staple crops is a critical factor for successful poverty reduction, it would have to be supported by the growth in other agricultural subsectors, as well as in nonagricultural sectors.

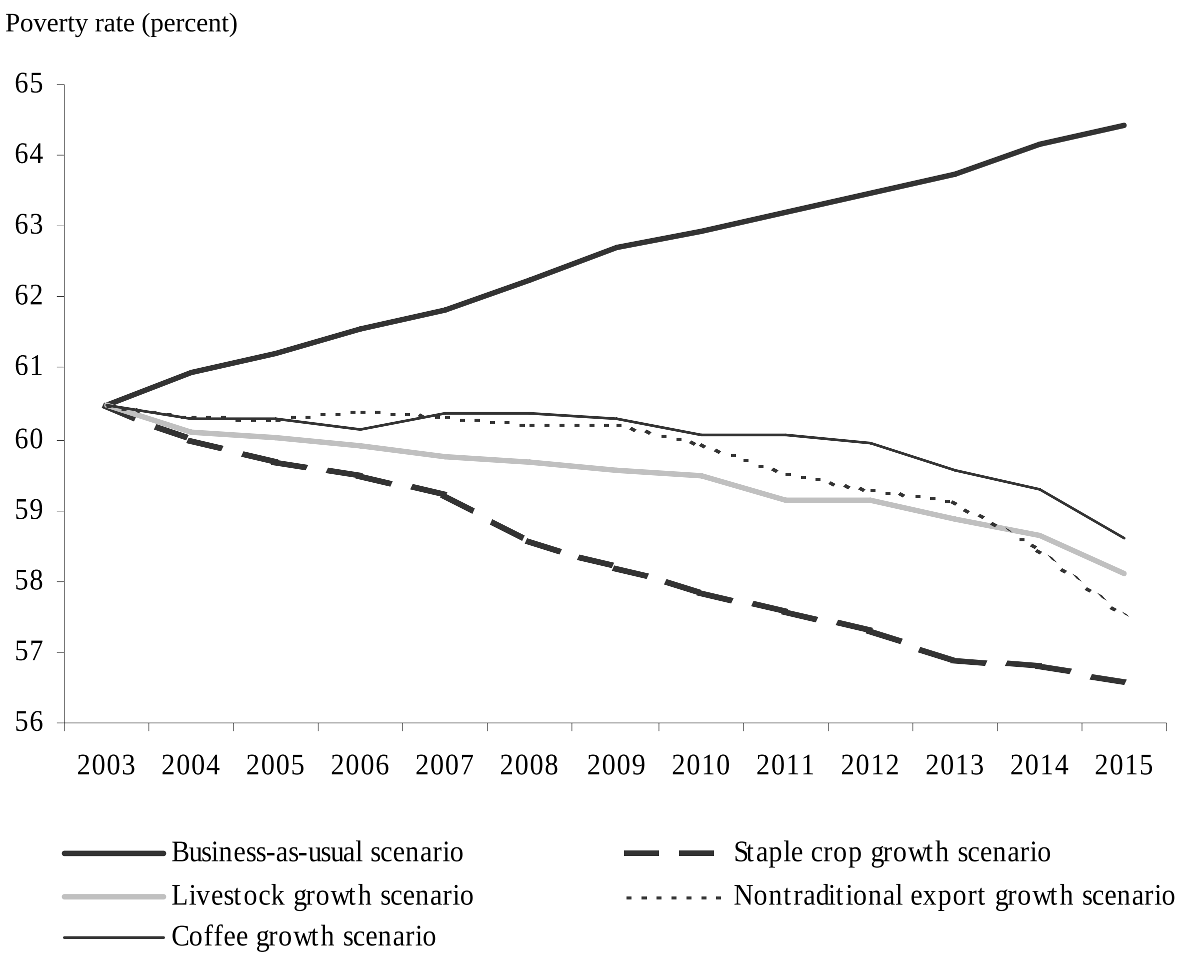
Combining growth in all four of Ethiopia's major agricultural subsectors could induce 5.1 percent growth per year in the overall economy, and 5.3 percent growth per year in agriculture. Such growth would reduce the poverty rate by as much 18 percentage points over the business-as-usual level, to 27.5 percent in 2015. Growth in staple crops and traditional and nontraditional exports would raise domestic demand for livestock products, in turn helping to stabilize livestock product prices, ultimately raising farmer incomes through increased livestock production. Similarly, growth in the livestock sector would generate feed demand for cereal crops. Increased income from growth in livestock and traditional and nontraditional exports would also help to stabilize the food crop prices.

Different Growth Options at the Regional Level

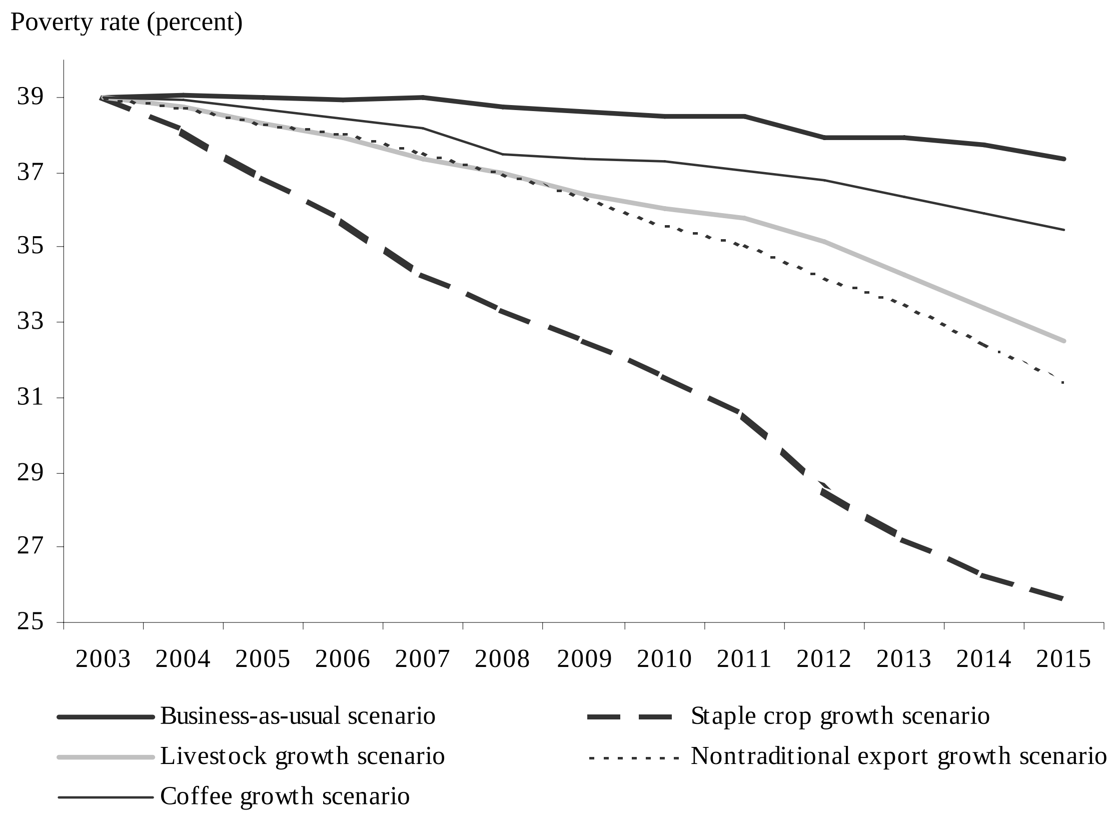
In addition to the national-level analysis discussed above, the model allows for assessment of the differential effects of the simulated growth options on poverty reduction across regions. For example, constant growth in staple crops causes the rural poverty rate to fall in the food surplus area from 39 to 25.7 percent, while in the food deficit area it only drops 4 percentage points, from 60.5 to 56.6 percent over the simulated timeframe (2003–15). While these results clearly show that staple crop growth is a strong driver of overall poverty reduction, it will not be sufficient to redress poverty in the food surplus area. Growth in other agricultural subsectors displays a similar differential effect on rural poverty reduction at the subnational level (Figure 4).

Figure 4. Comparison of Effect of Agricultural Subsector Growth on Poverty Reduction in the Food Deficit and Food Surplus Areas

A. Food Deficit Area



B. Food Surplus Area



Source: IFPRI model simulation results for Ethiopia, 2005.

The above analysis indicates the necessity for differential growth strategies across regions. A balanced agricultural growth strategy appears necessary for improving food security and rural income in the food deficit area, while growth in staple crops, especially cereals, will be the dominant driver in the food surplus area. Increased cereal surplus, however, needs to be diverted to meet demand beyond the food surplus area, making market and infrastructure development crucial, along with additional conditions to reduce farmers' postharvest risk (which, although not simulated in the model, is an extremely important factor in growth and poverty reduction). In the absence of these preconditions, staple crop production growth in the food surplus area would likely depress market prices, ultimately hurting rather than helping farmers.

To illustrate the need for different growth options across regions, a further scenario was developed based on a selection of commodities and subsectors that are important for income generation in the food deficit area. Table 7 presents the primary income-producing commodities for farmers across the three areas of differing food availability and at the national level. While crops account for 75 percent of national agricultural revenue on average, there is about 20 percent difference in average revenues between the food surplus and food deficit areas (60 versus 81 percent). This difference is especially significant for cereals, which account for 63 percent of agricultural revenue in the surplus area but less than 30 percent in the food deficit area. Roots and pulses account for nearly 20 percent of agricultural revenue in the food deficit area, making them another important group of crops for food security in that area.

Table 7. Share of Agricultural Revenue

Product	Food deficit area	Food balanced area	Food surplus area	National level
Crops	60.1	80.4	81.4	74.7
Cereals	28.5	53.4	63.0	49.5
Maize	7.4	9.4	15.5	11.1
Sorghum	8.2	15.5	6.2	9.9
Teff	4.9	12.4	16.5	11.7
Wheat	3.2	7.8	14.2	8.8
Roots	12.5	4.9	3.0	6.5
Pulses	6.9	10.0	7.9	8.3
Oilseeds	0.6	0.9	1.8	1.1
Fruits and vegetables	3.3	2.8	2.1	2.7
Coffee and chat	7.2	7.5	3.0	5.8
Other cash crops	0.9	0.9	0.6	0.8
Livestock	39.9	19.6	18.6	25.3
Cattle	16.3	6.5	6.4	9.4
Sheep and goats	1.7	0.5	0.4	0.8
Poultry	2.1	2.1	1.5	1.9
Dairy	3.9	3.2	4.4	3.8

Source: IFPRI model simulation results for Ethiopia, 2005.
Note: Total agricultural revenue for each area equals 100.

Using the above data, the food deficit area growth scenario was devised based on the income-generating potential of maize, sorghum, roots, and pulses, along with selected livestock products and two regionally dominant cash crops, coffee and chat. Further, the existing yield gap for food crops between the food deficit and food surplus areas was used as the basis for the 2.5–3.0 percent growth rate under the scenario. Simulation results indicate that this combination of growth has the capacity to induce a 17 percent increase in per capita agricultural income in the food deficit area by 2015. Growth of this magnitude would reduce the rural poverty rate in the area to about 52 percent in 2015, 9 percent lower than the baseline rate.

V. ACHIEVING AGRICULTURAL GROWTH

The pro-poor growth discussed in the preceding sections of this paper will only be feasible with significant investments in staple crops and livestock productivity. Hence it is important to assess the nature and extent of such investment.

Irrigation

Irrigation is naturally a critical component in reducing climate risk and improving crop production. Reducing climate risk can also help to induce the use of modern inputs, such as fertilizers and improved seeds, thereby further enhancing agricultural productivity. As of 2003, irrigated area in Ethiopia totaled about 200,000 hectares—slightly more than 2 percent of the total crop area. Of that irrigated area, 60 percent is planted to cereal crops and 40 percent to other (mainly cash) crops. According to data from the 1997 and 2000 agricultural sample surveys, the yield gap between irrigated and rainfed crop production is 40 percent, meaning that, on average, irrigation has the potential to increase cereal yields by up to 40 percent. Obviously, significantly increasing irrigation area would stimulate cereal production, but given that only 2 percent of cereal production and slightly more than 2 percent of other crop production is irrigated, it is unrealistic to expect that irrigation investment alone could generate the levels of cereals growth modeled in this study. Moreover, many researchers (for example, Fan and Hazell 2001) have shown strong diminishing returns to large-scale irrigation investment, implying that caution is needed in promoting large irrigation projects.

An irrigated area growth scenario was formulated based on Ethiopia's Irrigation Development Program, which is quite a moderate plan involving the development of about 274,000 hectares of additional irrigated area by 2015, 50 percent of which will be allocated to cereal crop production. Simulation results indicate that this level of expanded area will only increase irrigated cereal production to 3 percent of total cereal production in 2015, representing minimal additional annual growth: 2.1 percent compared with 1.9 percent under the business-as-usual scenario. It should be noted, however, that given the medium- to long-term nature of the program (meaning that projects are only completed toward the end of the simulation period), the potential returns are not fully captured within the simulation timeframe.

In terms of cash crops, irrigated area under this scenario triples by 2015 and hence accounts for 5 percent of all cash crop area compared with 2 percent as of 2003. This in turn increases exports; horticultural exports, for example, increase four-fold by 2015 over baseline levels, and coffee exports increase by about the same amount. As already discussed, however, such productivity increases will only reach domestic and international markets given improved infrastructure and market conditions. Consequently, the gains projected under the irrigated area growth scenario should not be understood to result solely from irrigation investment. Concurrent investments in markets and transportation are needed.

Table 8. Economic Growth and Poverty Rates under Different Investment Scenarios

Indicator	Base year[a] (1)	Irrigation (2)	Seed & fertilizer (3)	Three inputs (4)
Annual growth rate (percent)				
GDP	3.1	3.6	3.6	3.8
AgGDP	2.5	3.0	3.0	3.4
Poverty rate in 2015 (percent)				
National (baseline = 44.4)	45.7	41.9	41.5	38.8
Rural areas (baseline = 45.8)	48.0	43.9	43.5	40.1
Food deficit area (baseline = 60.5)	64.4	58.8	61.1	56.4
Food surplus area (baseline = 39.0)	37.3	34.5	30.5	27.9

Source: IFPRI model simulation results for Ethiopia, 2005.
[a]*2003.*

Taking into account the increased irrigated area, improved infrastructure and market access, and the associated linkage effects in the economy, GDP increases at 3.6 percent per year compared with 3.1 under the business-as-usual scenario, and AgGDP increases to 3.0 percent per year compared with 2.5 percent. As a result, the national poverty rate falls to 41.9 percent in 2015 compared with a baseline level of 45.7 (Table 8). While irrigation has a modest effect on national-level poverty, its effect in the food deficit area is significant, given that most of the increased irrigated are is located there. The rural poverty rate in this area falls to 58.8 percent in 2015, compared with 64.4 percent under the business-as-usual scenario.

Adoption of Improved Seed

The low yields prevalent in Ethiopian agriculture are generally attributed to low usage and efficiency of modern inputs. National survey data show that, while about 40 percent of cereal production benefits from the use of fertilizer, only about 10 percent also gains from other inputs, such as improved seed or irrigation. The average yield gap in cereal production due purely to lack of fertilizer is actually quite small. Total cereal yields where fertilizer is used are about 1.4 metric tons per hectare, 20 percent higher than yields without the use of any modern inputs. Many studies report similar findings regarding fertilizer use. For example, based on a household- and plot-level survey conducted in 100 villages in the Tigary region, Pender and Gebremedhin (2004) find that fertilizer use is associated with yield increases of 14 percent (with a weak statistical significance). Using the Ethiopia Rural Household Survey (ERHS) for 1994, Croppenstedt and Demeke (1997) report fertilizer elasticities in the range of 0.03 to 0.09 in the production function. Yao (1996) reports elasticities in the range of 0.05 to 0.10, based on aggregated time-series data.

There are many reasons for this disappointing outcome. Abrar, Morrissey, and Rayner (2004), for example, find that average fertilizer application in Ethiopia falls within the low range of 10–50 kilograms per hectare—considerably lower than the recommended rate of 150–200 kilograms.[6] Pender and Gebremedhin (2004) emphasize the complementary effect of fertilizer use with soil and water conservation investment and land management. Both irrigation and stone terrace technology are associated with increased fertilizer and other modern input use, and their joint effect on land productivity

[6] The Agricultural Census data (CSA 2001/02), which is aggregated to *woreda* level, does not support this finding, at least for maize production. Among the 226 woredas that report fertilizer use in maize production, the per hectare fertilizer application averages 130 kilograms. Fertilizer application averages more than 150 kilograms per hectare in one-third of *woredas* and over 100 kilograms per hectare in two-thirds of *woredas*.

is significant in Tigray. Farming practices also affect fertilizer efficiency. Howard et al. (2003) find plowing four or more times before planting can increase yields by 550 kilograms per hectare. Later planting reduces yields by 280–315 kilograms per hectare, and failure to weed on time results in average losses of about 220 kilograms per hectare.

Lack of agricultural extension services may result in a knowledge gap for farmers when it comes to adopting modern technologies, including fertilizer, properly. Ayele, Kelemework, and Alemu (2003) report that even though the number of agricultural extension agents has significantly increased in Ethiopia in recent decades, the national ratio of staff to farm households was still only 1:700 as of 2000. A high degree of inefficiency of fertilizer use among cereal farmers was found by Croppenstedt and Mulat (1997). They estimated mean efficiencies at 40 percent for fertilizer compared with 76 percent for land and 55 percent and labor. Badly timed application may also contribute to low fertilizer use efficiency. This is partially due to the inability of farmers to acquire fertilizer and fertilizer credit when needed. Production and price risk and resource availability are all found to affect farmers' decisions regarding both fertilizer use and its proper application. High price, output, and hence profit variability make investment in inputs risky for farmers (Snapp, Blackie, and Donovan 2003.) Van den Broeck (2001) finds weather risk to be associated with fertilizer use. In the case of good weather, fertilizer use can result in a 29 percent higher output value compared with non-use; however, in the case of bad weather, it can lead to 30 percent lower output values.

If fertilizer is used with improved seed in cereal production, Agricultural Census data show that average yields increase to 2.5 metric tons per hectare, doubling the level achieved without modern inputs. This outcome is consistent with the findings of Howard et al. (2003). Based on a maize plot survey in the Oromiya region, average maize yields were 70 percent higher when improved seed and fertilizer were used compared with traditional seed and no fertilizer, and there is still a 40 percent potential for further improvement based on results from research stations. The econometric analysis conducted by the authors also supported their findings.

While significant gains in cereal production are possible from a combination of fertilizer use and improved seed, survey data show that only about 4 percent of cereal area has been grown employing such technologies. Some studies associate the low adoption of improved seed with the quality and price of seed, which may result from lack of competition in both seed production and distribution (Crawford et al. 2003). Further, adopting any modern technology often requires changes in crop or land management, and, once again, in the absence of education, training, and extension services, farmers understandably find it difficult to move beyond longstanding traditional farming practices. Learning new skills and monitoring input and output prices are integral to modern technology adoption. (Weir 1999)

Notwithstanding these complex issues, a modern input use scenario was devised, combining the use of improved seed and fertilizer in cereal production. The simulation results show that additional annual cereal production growth of 0.9 percent can be achieved through this strategy, ultimately reducing the rural poverty rate by 4.5 percentage points over baseline levels to 43.5 percent in 2015 (Table 8).

Adoption of Modern Seed Varieties with Increased Irrigation

Obviously, returns to technology adoption are low when modern inputs are used in isolation. For this reason, a further scenario was formulated combining the adoption of modern seed varieties with improved fertilizer-use efficiency and expanded irrigated area. This combination results in annual cereal production growth of 3 percent, in turn inducing average GDP growth of 3.8 percent per year, and AgGDP growth of 3.4 percent per year. Growth in cereal production together with increased cash crop production through irrigation investment contributes to reducing the poverty rate to 38.8 percent—5.6 percent lower than comparable levels under the business-as-usual scenario and comparable with results under the staple crop growth scenario.

Promoting Modern Technology in Livestock Production

Ethiopia has the largest livestock sector in East Africa, with a stock of 42 million cattle and 46 million sheep and goats. More than 60 percent of the cattle are raised in the highland area, following a typical mixed crop–livestock system, and 60 percent of the sheep and goats are raised in the lowlands, which are dominated by pastoral systems. The livestock sector plays multiple roles in the country's rural economy. Live animals, especially cattle, are the most important source of cash income for many farmers; large animals are the dominant asset; draught animals are virtually the only capital input in crop production for most small farmers; and milk is one of the main sources of protein in the diet, especially for children.

Traditional technology plays a dominant role in livestock production. Except in Addis Ababa, the number of hybrid and exotic cows is extremely low, and grazing and crop residues are often the only sources of animal feed. Because of the low use of modern technologies and inputs, livestock productivity is extremely low. Yields from milking cows, for example, are among the lowest in East Africa. The average yield in Ethiopia per cow is about 270 liters per year compared with 500 liters in Kenya, 480 liters in Sudan, 400 liters in Somalia, and 350 liters in Uganda (Muriuki and Thorpe 2001). Once modern technology is adopted, livestock productivity is significantly improved. In Addis Ababa, for example, almost 50 percent of milking cows are of cross-bred and exotic varieties, while for the country as a whole the ratio is less than 2 percent. Given the comparatively high ratio of modern technology adoption in Addis Ababa, together with modern input use and favorable market conditions, yields from milking cow are two to three times higher than the national average.

To simulate the effect of increased technology adoption in the livestock sector on income growth and poverty reduction, a second livestock growth scenario was modeled focusing on the three main commodities: milk, beef, and poultry. In the case of milk, the ratio of cross-bred milking cows was increased in line the existing 20 percent share in Kenya, representing more than 10-fold growth. Achieving this means an additional 4.5 percent annual growth in milk production. According to Fernandez-Rivera, Okike, and

Ehui (2001), the potential for increasing beef yields is significantly lower than the potential for increasing milk yields. As of 2001/02, 40 percent of cattle in Ethiopia were draught animals—the most important source of beef—which in part explains the low efficiency of beef production. Most draught animals can be kept 10 years or more as working animals, and meat production is just a by-product. Under this scenario, similar growth was assumed through the adoption of modern technologies in beef production as was assumed for milk production (approximately 20 percent per year). However, because the technology adoption rate is lower for beef production than for milk production (less than 0.5 percent), the resulting overall growth in beef production is much lower (again, only about 0.5 percent). Because of insufficient data on technology adoption and yield levels for poultry, the yield gap between South Africa and Ethiopia was used to establish appropriate levels of growth, resulting in an increase of 0.8 percent over total 2001/02 levels. On this basis, the annual growth rate in poultry production translates to 1.5 percent.

The combination of milk, beef, and poultry production growth under this scenario results in an additional 3.8 percent overall annual growth in livestock products. Milk is the dominant contributor to this result, while beef and poultry play only marginal roles. This increased growth is similar to results from the earlier livestock growth scenario, implying that reasonably high growth in the Ethiopian livestock sector is feasible by increasing the adoption of modern technology to 30 percent of total production (compared with the 2001/02 level of only 10 percent). This magnitude of livestock sector growth has the potential to induce 3.7 percent GDP growth and 3.3 percent AgGDP growth per year over the projection period, compared with 3.1 and 2.5 percent, respectively, under the business-as-usual scenario. The resulting effect on poverty, however, is slightly less for this scenario, under which the 2015 poverty rate falls to about 42 percent, than for earlier livestock growth scenario, under which the 2015 poverty rate falls to about 40 percent. The reason for the comparatively weak linkages between livestock growth and poverty reduction in the current scenario is that increased use of modern livestock technologies usually occurs in areas where such technologies are already in use—generally areas where the poverty rate is below the national average. Modern livestock technologies are rarely known of or applied by farmers in areas where poverty is particularly high. Thus, modern technology adoption may not initially benefit the poorest people—which is consistent with the findings of Hazell and Ramasamy (1991) for the early stages of the Green Revolution in India; specific targeting policies that encompass increased education and extension, as previously discussed, will also be needed.

Halving the Poverty: Markets and Nonagriculture Matter

An agriculture-led growth strategy does not imply that investments should be in agriculture only. Many studies have shown that poor infrastructure and dysfunctional markets prevent farmer access thereby diminishing the profitability of agriculture (Kelly et al. 2003). It is important to remember that institutional barriers also constrain farmers from becoming actively involved in market activities, and market development does not solely imply infrastructure investment (Gabre-Madhin 2001). Nonetheless, this section focuses specifically on the growth and poverty effect of reducing transportation costs associated with agricultural trade and improving market access for farmers.

Ethiopian road density is 27 kilometers per 1,000 km2, slightly more than half the 50 kilometers per 1,000 km2 average for Africa as a whole. Seventy percent of Ethiopian farmers are reportedly more than half a day’s walk away from an all-weather road. The combination of this poor market access and high transportation costs significantly increases the gap between consumer and producer prices, which ultimately lowers the farmgate prices received by affected farmers. The average grain price gap is estimated to be about 30 to 70 percent across regions, and domestic marketing costs can account for more than 50 percent of fertilizer prices paid by farmers (Jayne et al. 2003). These additional costs significantly reduce the profitability of increased production on the part of farmers.

In this section, decreased market costs resulting from increased investment in roads and other market infrastructure are simulated. Constrained by available information on the quantitative relationship between market costs and investment in such infrastructure in Ethiopia, two main assumptions were made: (a) investment lowers the marketing margins between the food surplus and food deficit areas, and (b) improved infrastructure will reduce the price gap between the food surplus and food deficit areas by 10 percent per year, such that market prices across zones will converge by 2015 (representing an overall decrease in the price gap of 70 percent). It is further assumed that lower marketing costs are associated with improved service sector productivity, and by 2015 such productivity increases by 15 percent over baseline levels (a 1 percent increase per year).

Once growth in the agricultural sector is combined with improved marketing margins through cross-sector linkage effects, GDP growth increases to 5.8 percent per year, and AgGDP growth increases to 5.4 percent per year. Reducing marketing costs primarily benefits smallholders via the increased prices they receive for their goods, increasing their income from the same level of output. Moreover, improving market conditions creates a more efficient trading sector (as part of the service sector), which itself can generate greater nonagricultural income at constant costs. Due to such cross-sector linkages and positive price effects, the poverty rate under this scenario is significantly lowered, drawing the objective of halving poverty rate by 2015 within reach. Moreover, the pro-poor effect of the resulting growth is much stronger in rural areas, where simulation results indicate the poverty rate drops to 25 percent by 2015 from the 2003 level of 45.8 percent (Table 9).

While market improvement supports agricultural growth and generates additional nonagricultural growth (though mainly in trade-related services), broad nonagricultural growth, including manufacturing and other services, is also critical in meeting MDGs. Nonagricultural growth not only creates nonfarm opportunities and rural income but also increases urban income; further, rural nonfarm income creates market demand for agriculture. Cross-sector linkage effects induce 1 percent nonagricultural growth per year over and above the agricultural growth and market improvement discussed above (and in addition to the historical trend of 3.7 percent). As a result, GDP grows at 6.1 percent and agriculture at 5.5 percent per year. With such growth, the national poverty rate falls to 23 percent, sufficient to halve the 2003 poverty rate in 2015 (Table 9).

Table 9. Markets and Nonagriculture Matter for Halving the Poverty

Indicator	Base year[a]	Multi-agriculture[b] (1)	Markets[c] (2)	Agriculture & nonagriculture[c] (3)
GDP growth rate (percent)	3.1	5.1	5.8	6.1
Ag GDP growth rate (percent)	2.5	5.3	5.4	5.5
Calories pc per day by 2015 (baseline = 1,834)	1,715	2,117	2,165	2,181
Poverty rate by 2015 (baseline = 44.4)	45.7	27.5	24.4	23.4

Source: IFPRI model simulations results for Ethiopia, 2005.
[a] *2003*
[b]*An additional 1.5 percent annual growth for staples, 3.4 percent for livestock, and 9 percent for nontraditional exports.*
[c]*As outlined under note b, plus market improvement (10 percent annual reduction in marketing margins and 1 percent additional annual growth in services).*
[d]*As outlined under note c, plus an additional 1 percent annual growth in other nonagriculture.*

VI. CONCLUSIONS

Ethiopia faces dire challenges in alleviating poverty, let alone meeting the Millennium Development Goal of halving the incidence of poverty by 2015 (compared with 2000 levels). By continuing a business-as-usual growth path, the simulations undertaken for this study indicate that food security would only deteriorate further. In fact, in the absence of agricultural growth, the country's poverty rate would rise even higher, leaving as many as 10 million additional people in poverty by 2015.

Modeling results indicate that, within agriculture, staple crops have the greatest capacity to contribute to poverty reduction. Based on annual growth of 3.4 percent per year, (1.5 percent additional productivity growth above baseline levels) staple food growth would support economic growth in the order of 4 percent and agricultural growth of about 3.5 percent per year. In response, the poverty rate in Ethiopia would fall from its 2000 level of 44.4 percent to about 37 percent in 2015. Yet this is insufficient. Far more rapid agricultural growth, and thus poverty reduction, results by combining growth in staple crops with growth in livestock and exports. With this strategy, annual agricultural growth increases by more than 5 percent, in turn eroding the poverty rate to 27.5 percent in 2015.

At the subnational level, similar rates of agricultural subsector growth have different effects on the associated poverty rates, necessitating regionally based strategies for growth and poverty reduction. As of 2001/02, more than 50 percent of Ethiopia's poor people lived in the food deficit area, where household food availability averages half the national level. While growth in staple crops, especially cereals, must be fundamental to any significant poverty reduction strategy, success also depends on improved infrastructure and market access. Food availability per rural household is already 70 percent higher than the national average in the food surplus area and surpluses are projected to reach more than 45 percent of cereal output in many zones within that area by 2015. In the absence of improved market conditions, growth in staples will be difficult to achieve and increased grain production could harm farmers by depressing prices in the food surplus area. Thus, market development and access should be an integral component of agricultural development strategies.

Increasing national food availability by 50 percent by 2015 would significantly contribute to poverty reduction. The goal is technically feasible if accompanied by additional approaches. The country's yield gap between traditional and modern technologies must be reduced. Given appropriate investment, doubling irrigated area and improving the dissemination of modern technologies could induce the use of improved seed and enhance fertilizer-use efficiency, making a significant contribution to staple crop growth. Results from model simulations indicate that increasing Ethiopian livestock productivity to existing Kenyan levels would also make a valuable contribution to economic growth and poverty reduction.

While agriculture can play a central role in growth and poverty alleviation in Ethiopia, nonagricultural growth and enhanced market conditions are also critical to a balanced growth strategy. When the growth described above is augmented by reduced market costs and an additional 1 percent annual growth in nonagriculture, simulation results indicate that growth in both GDP and AgGDP could reach about 6 percent per year, enabling the national poverty rate to decline to 23 percent in 2015.

APPENDIX A: AGRICULTURAL COMMODITIES INCLUDED IN THE MODEL

Maize, Teff, Wheat, Sorghum, Barley, Millet, Oats, Rice,
Potatoes, Sweet potatoes, Enset, Other root crops,
Beans, Peas, Other pulses,
Groundnuts, Rapeseed, Sesame, Other oil crops,
Domestic vegetables, Bananas, Other domestic fruits,
Exportable vegetables, Other horticultural crops, Chat, Cotton,
Coffee,
Sugar, Beverages and spices
Bovine meat, Goat meat and mutton, Other meat,
Milk and dairy products,
Poultry and eggs, Fish

APPENDIX B: MODEL EQUATIONS

Supply Functions

Yield Function (for crops)

$$Y^{q}_{R,Z,i,t} = \mathrm{YA}^{q}_{\mathrm{R,Z,i,t}} P^{\alpha^{q}_{R,Z,i}}_{R,Z,i,t}, \tag{1}$$

where $Y^{q}_{R,Z,i,t}$ is the yield for crop *i* with technology *q* in region *R* and zone *Z* at time period *t*, and $P_{R,Z,i}$ is the producer price for *i* and can be different across regions or zones. $YA^{q}_{R,Z,i,t}$ is the productivity shift parameter, which varies according to different technologies, *q*. $\mathrm{YA}^{q}_{R,Z,i,t}$ could be estimated as a function of modern inputs, such as irrigation, fertilizer, and improved seed, were more data available. Currently, the model only captures the mean difference across technologies. There are a total of 15 different technologies for the major (mainly cereal) crops, which implies that there are 15 yield functions per crop per zone;, maize, for example, is characterized by the different level of $\mathrm{YA}^{q}_{R,Z,i,t}$, which changes over time:

$$\mathrm{YA}^{q}_{R,Z,i,t+1} = \mathrm{YA}^{r}_{\mathrm{R,Z,i,t}}\left(1 + g_{Y_{R,Z,i}}\right), \tag{2}$$

where $g_{Y_{R,Z,i}}$ is the annual productivity growth rate.

Area Function (for crops)

$$A^{q}_{R,Z,i,t} = \mathrm{AA}^{q}_{\mathrm{R,Z,i,t}} \prod_{j} P^{\beta_{R,Z,j}}_{R,Z,j,t}, and \sum_{j}^{J} \beta_{R,Z,j} = 0, \tag{3}$$

where $A^{q}_{R,Z,i,t}$ is the area for crop *i* with technology *q*, and P_1, P_2, … P_J, are the producer prices for all commodities; $\mathrm{AA}^{q}_{R,Z,i,t}$ is the shift parameter, which captures the area expansion:

$$\mathrm{AA}^{q}_{R,Z,i,t+1} = \mathrm{AA}^{\mathrm{q}}_{\mathrm{R,Z,i,t}}\left(1 + g_{A_{R,Z,i}}\right), \tag{4}$$

where $g_{A_{R,Z,i}}$ is the annual area expansion rate for crop *i* with technology *q*. Given most prices are endogenous in the model, area functions, similar to the supply functions for noncrop production, capture cross-sector linkages among crops, between crop and noncrop agriculture (such as livestock), and between agriculture and nonagriculture.

Total Supply of Crops

$$S_{R,Z,i,t} = \sum_q Y^q_{R,Z,i,t} \cdot A^q_{R,Z,i,t} \, . \tag{5}$$

Supply Function for Noncrop Sectors (livestock and nonagriculture)

$$S^{LV}_{R,Z,i,t} = \mathrm{SA}^{\mathrm{LV}}_{\mathrm{R,Z,i,t}} \prod_j P_{R,Z,j,t}^{\beta^{LV}_{R,Z,j}} \, . \tag{6}$$

Trends in the livestock and nonagricultural supply function are represented by:

$$\mathrm{SA}^{\mathrm{LV}}_{\mathrm{R,Z,i,t+1}} = \mathrm{SA}^{\mathrm{LV}}_{\mathrm{R,Z,i,t}} \left(1 + g_{S_{R,Z,i}}\right), \tag{7}$$

where $g_{S_{R,Z,i}}$ is the annual growth rate of livestock and nonagricultural productivity and varies by region or zone and commodity, and g_Y, g_A, and g_S are exogenous variables in the model.

With regional disaggregation and commodity details, it is infeasible to estimate the supply elasticities used in the model. Thus, a modest own-price elasticity of 0.2 is chosen for the supply function.[7] The negative cross-price elasticities in the function are then derived from the own-price elasticity multiplied by the value share of each commodity (at the zonal level). The homogeneity of degree zero condition is imposed on the supply function such that, within each time period, there is no supply response if all prices change proportionally. The constraint on crop area function is also imposed to avoid a simultaneous expansion of all crop areas over a given time period.

[7] Using an aggregate, normalized quadratic profit function (at mean values of prices and fixed factors) Abrar, Morrissey, and Rayner (2004) estimate the own-price elasticity of output to be around 0.013 in dual and 0.08 in primal, which are significant. As an aggregate profit function is considered, the substitution possibility is abstracted.

Demand Functions

Zonal Level per Capita Demand is a Function of Prices and Income

$$Dpc_{R,Z,i,t} = \prod_j PC_{R,Z,j,t}^{\varepsilon_{R,Z,i,j}} GDPpc_{R,Z,t}^{\varepsilon_{R,Z,i}^{I}} , \tag{8}$$

where $Dpc_{R,Z,i}$ is per capita demand for commodity *i* in region *R* and zone *Z*, and $PC_{R,Z,j}$ is the consumer price for *j* in region *R* and zone *Z*. *j* = 1,2,…,36 (including two aggregate nonagricultural goods.) $GDPpc_{R,Z}$ is per capita income for region *R* and zone *Z*'s rural or urban consumers. $\varepsilon_{R,Z,i,j}$ is price elasticity between demand for commodity *i* and price for commodity *j*, and $\varepsilon_{R,Z,i}^{I}$ is income elasticity such that $\sum_{j}^{J} \varepsilon_{R,Z,i,j} + \varepsilon_{R,Z,i}^{I} = 0,$ and $\sum_{j}^{J} sh_{R,Z,j} \cdot \varepsilon_{R,Z,j}^{I} = 1,$ where $sh_{R,Z,i}$ is the expenditure share of commodity *i*.

Relationship Between Producer and Consumer Prices

It is assumed that import and export parity prices are the border prices adjusted by trade margins. National market prices are represented by the prices in Addis Ababa, while prices at the zonal level are linked to, but different from, national market prices. Prices are higher in the food deficit area and lower in the food surplus area compared with national market prices. The farther the zone from the nearest major market centers, the lower the prices. The difference between zonal-level prices and those at national markets is defined as regional market margins. Specifically, for imported commodities, the following relationship exists between import parity prices and consumer prices in national markets:

$$PC_{i,t}^{Addis} = (1 + Wm_i) \cdot PWM_i , \tag{9}$$

where Wm_i is the trade margin between border prices, PWM_i, and consumer prices, PC_i, in national markets when commodity *i* is importable. The relationship between zonal-level and national market prices (for consumer prices) is as follows:

$$PC_{R,Z,i,t} = (1 + Dgap_{R,Z,i}) \cdot PC_{i,t}^{Addis} , \tag{10}$$

where $Dgap_{R,Z,i}$ is negative if Z is in food surplus area and positive if Z is in the food deficit area.

National market prices and export parity prices for exportable commodities have the following relationship:

$$P_{i,t}^{Addis} = \left(1 - Wm_i\right) \cdot PWE_i \,, \tag{11}$$

where P is producer prices and PWE is border prices; the equation holds only when commodity i is exportable. Consumer and producer prices are not necessary the same, such that:

$$PC_{R,Z,i,t} = \left(1 + Dm_{R,Z,i}\right) \cdot P_{R,Z,i,t} \,, \tag{12}$$

where Dm is the margin between consumer and producer prices. The following relationship exists between domestic market and import/export parity prices for nontradable commodities:

$$(1 - Wm_i) \cdot PWE_i < P_{i,t}^{Addis} \leq PC_{i,t}^{Addis} < \left(1 + Wm_i\right) \cdot PWM_i \,. \tag{13}$$

Exports and Imports

Trade (either in imports or exports) is determined by the difference between national market prices and import/export parity prices, that is, where

$$P_{i,t}^{Addis} = \left(1 - Wm_i\right) \cdot PWE_i \,,\; E_{i,t} > 0; \tag{14}$$

otherwise, $E_{i,t}$ = 0. E_i is exports of commodity i; and if

$$PC_{i,t}^{Addis} = \left(1 + Wm\arg in_i\right) \cdot PWM_i \,,\; M_{i,t} > 0; \tag{15}$$

otherwise, $M_{i,t}$ = 0. M_i is imports of commodity i.

Notice that E_i and M_i can be zero in the early stages in the model; hence, the prices for nontraded goods are endogenously determined. If the domestic consumer prices, PC_i, rise over time (but not the border prices) due to increased demand more than the increased supply, PC_i starts to approach $(1 + Wm_i)PWM_i$. Once $PC_i = (1 + Wm_i)PWM_i$, imports occur for commodity i, and PC is linked to PWM, which is exogenous. A similar but opposite situation holds for P_i, that is, if P falls over time such that $P_i = (1 - Wm_i) PWE_i$, exports occur and P is linked to PWE.

Regional Crop Deficit and Surplus

The model can identify which zones are food deficit or food surplus, but it cannot identify trade flows among zones. That is, total deficits and surpluses are cleared (balanced) in the national market and no regional differential market exists. Crop i is in deficit (surplus) if the following equation is positive (negative):

$$DEF_{R,Z,i,t} = Dpc_{R,Z,i,t} \cdot PoP_{R,Z,t} - S_{R,Z,i,t} . \tag{16}$$

Balance of Demand and Supply at the National Level

$$\sum_{R,Z} S_{R,Z,i,t} + M_{i,t} - E_{i,t} = \sum_{R,Z} Dpc_{R,Z,i,t} \cdot PoP_{R,Z} . \tag{17}$$

This equation solves for the price of commodity i if both M and E are zero. Otherwise, it solves for the value of M or E.

GDP and Per Capita Zonal Income Function

Income in the model is endogenous and determined by production revenues. Given that the model does not explicitly include input and, hence, the costs of input, the prices for agricultural commodities are adjusted such that the sector production revenues are close to the value-added for this sector:

$$GDP_{R,Z,t} = \sum_j P_{R,Z,j,t} \cdot S_{R,Z,j,t} \, .. \tag{18}$$

Income per capita:

$$GDPpc_{R,Z,t} = \frac{GDP_{R,Z,t}}{PoP_{R,Z,t}} . \tag{19}$$

Poverty Population and Poverty Rate

HICES data are linked to per capita income solved in the model, such that the model can calculate both the population in poverty and the average poverty rates for rural, urban, and national areas. Given zonal-level income distribution, the share of the each household group (represented by the sample household, and weighted by the sample size taking the household size into account) is constant and linked to zonal-level rural or urban total income, endogenously solved in the model. The poverty line is constant, but differs between rural and urban areas, hence, the income levels used in the poverty analysis are in real term (meaning GDP is deflated by a price index). The new poverty population for either rural or urban areas or at a specific subnational level is obtained by comparing the newly solved (per capita) income for each time period with the constant poverty line. The poverty rate is the ratio of the new poverty (rural or urban) population over the total (rural or urban) population, updated with an exogenous population growth.

Specifically, let $PoorInc_t^{rur}$ be the (per capita) poverty line income for rural areas and $GDP_{R,Z,t}^{rur}$ be total rural income in region *R* and zone *Z* at time *t*; let $Sh_{R,Z,h}^{rur}$ be income share for rural household group *h* in region *R* and zone *Z*; the population $Pop_{R,Z,h,t}^{rur}$ of household group *h* equals the sample weights multiplied by the household size, represented by the sample household for group *h* updated with the population growth rate. Hence, the income of household group *h* is defined as:

$$I_{R,Z,h,t}^{rur} = Sh_{R,Z,h}^{rur} \cdot GDP_{R,Z,t}^{rur}; \sum_h Sh_{R,Z,h}^{rur} = 1. \quad (20)$$

Per capita income in this household group is

$$Ipc_{R,Z,h,t}^{rur} = \frac{I_{R,Z,h,t}^{rur}}{Pop_{R,Z,h,t}^{rur}}. \quad (21)$$

Whether the population in group *h* is included in or excluded from the poverty new population depends on the following condition:

$$Pop_{R,Z,h,t}^{rur} \text{ is in the poverty population if } Ipc_{R,Z,h,t}^{rur} < PoorInc_t^{rur}. \quad (22)$$

Notice that since the available information on income is by household group (represented by the sample household), we cannot separately estimate poverty within each group. That is, if $Ipc_{R,Z,h,t}^{rur} < PoorInc_t^{rur}$, all the population within group *h* is defined as the poverty population. The same is the case for $Ipc_{R,Z,h,t}^{rur} \geq PoorInc_t^{rur}$.

The total poverty population in rural area is the sum of $Pop_{R,Z,h,t}^{rur}$ over *h* for all *h* with $Ipc_{R,Z,h,t}^{rur} < PoorInc_t^{rur}$. The poverty rate is calculated by the ratio of this number over the total rural population. The urban poverty population and poverty rate can be defined using a similar method. As poverty population is defined at the household group level, the poverty rate can easily be calculated at a specific subnational level, such as for the food deficit area or country as a whole.

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