8 Implications of Accelerated Agricultural Growth for Household Incomes and Poverty in Ethiopia: A General Equilibrium Analysis

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Ethiopia's economy has experienced rapid growth in recent years. Although growth in agricultural gross domestic product (GDP) from 1998 to 2007 was less rapid than in other parts of the economy, agriculture also performed well, growing faster than the rural population. However, poverty is still severe in Ethiopia and is concentrated in rural areas. To accelerate growth and poverty reduction, Ethiopia's national strategy affords an important role to agriculture as a source of both growth and development for the broader economy. This is essential given that agriculture is an income source for most of the population. The sector accounts for more than two-fifths of GDP and three-fourths of merchandise export earnings, and it provides key inputs into the manufacturing sectors, whose agricultural processing sectors contribute further to national GDP. In parallel to Ethiopia's agricultural strategy, the New Economic Partnership for Africa's Development (NEPAD) is in the process of implementing the Comprehensive Africa Agriculture Development Programme (CAADP) together with African governments. The CAADP initiative supports the identification of an integrated framework of development priorities aimed at restoring agricultural growth, rural development, and food security in the African region. The main target of CAADP is achieving 6 percent agricultural growth per year in low-income African countries like Ethiopia.

Because choices are involved within the agricultural sector, both for the sector as a whole and across subsectors, many investment and policy interventions will be designed at the subsector level. However, strong interlinkages occur across subsectors and between agriculture and the rest of the economy. To understand these linkages and how sectoral growth could contribute to the country's broad development goals, an integrated framework is needed in order to synergize the growth projections among different agricultural commodities or subsectors and evaluate their combined effects on economic growth and poverty reduction.

Moreover, agricultural production growth is often constrained by demand in both domestic and export markets, and demand, in turn, depends on income growth both in agriculture and in the broader economy. Although agriculture is

a dominant economic activity in Ethiopia and a majority of the population lives in rural areas, both rural and urban sectors need to be included in this framework in order to understand the economywide impact of agricultural growth.

This chapter analyzes agricultural growth projections that can support the design of a more comprehensive rural development component under Ethiopia's agricultural strategy that is also in alignment with the principles and objectives collectively defined by African countries as part of the broader NEPAD agenda. In particular, this chapter seeks to position Ethiopia's agricultural sector and rural economy within the country's national strategy. For these purposes, and to assist policymakers and other stakeholders to make informed long-term decisions, a new economywide model for Ethiopia has been developed and used to analyze the linkages and trade-offs between economic growth and poverty reduction at both macro- and microeconomic levels. The results from the model simulations are intended to guide debate in prioritizing the potential contributions of different subsectors to Ethiopia's achievement of its broader development objectives.

Modeling Sources of Agricultural Growth and Poverty Reduction

The Dynamic Regional Economywide Model of Ethiopia

A new Ethiopian computable general equilibrium (CGE) model was developed to capture (1) trade-offs and synergies from accelerating growth in alternative agricultural subsectors, (2) the economic interlinkages between agriculture and the rest of the economy, and (3) the effects of alternative sources of growth on household incomes and poverty. This model is called the Dynamic Regional Economywide Model of Ethiopia (DREME).[1] Although this chapter focuses on the agricultural sector, DREME also contains information on the nonagricultural sectors. In total, DREME identifies 69 subsectors, 24 of which are in agriculture (Table 8.1). Agricultural crops fall into five broad groups: (1) cereals, which is separated into teff, barley, wheat, maize, sorghum, and millet; (2) pulses and oilseeds, which is separated into pulses, such as beans, and oilseed crops, such as groundnuts; (3) horticulture, which is separated into fruits, vegetables, and *enset;* (4) higher-value export-oriented crops, which is separated into cotton, sugarcane, tobacco, coffee, tea, and cut flowers; and (5) other crops, which includes *chat* and other staples such as root crops. DREME also identifies four livestock subsectors, including cattle, milk, poultry, and other animal products.

1. The core model is described in detail in Diao and Thurlow (2012). See Table 8A.1 in the appendix for the model sets, parameters, and variables and Table 8A.2 for the model equations. Earlier CGE models for Ethiopia, however, have not included detailed disaggregation of the agriculture sector or of households by region (for example, Gelan 2002; Lofgren and Diaz-Bonilla 2005). See Diao and Nin Pratt (2007), where a fixed-price multiplier analysis using a 1999/2000 social accounting matrix of Ethiopia is combined with a detailed regionally disaggregated multimarket model to analyze the growth and poverty implications of alternative production scenarios.

TABLE 8.1 Sectors in the Dynamic Regional Economywide Model of Ethiopia

Groups (number of sectors in group)	Sectors
Cereals (5)	Teff, barley, wheat, maize, sorghum
Pulses and oilseeds (2)	Pulses, oilseeds
Horticulture (3)	Vegetables, fruits, *enset*
Export crops (6)	Cotton, sugarcane, tea, tobacco, coffee, cut flowers
Other crops (2)	*Chat*, other crops
Livestock (4)	Cattle, milk, poultry, animal products
Other agriculture (2)	Fisheries, forestry
Agroprocessing (10)	Meat, dairy, vegetable products, grain milling, milling services, sugar refining, tea processing, other food processing, beverages, tobacco processing
Other manufacturing (18)	Textiles, yarn, fibers, lint, clothing, leather products, wood products, paper and publishing, petroleum, fertilizer, chemicals, non–metallic minerals, metals, metal products, machinery, vehicles and transport equipment, electronic equipment, other manufacturing
Other industry (6)	Coal, natural gas, other mining, electricity, water, construction
Services (11)	Wholesale and retail trade, hotels and catering, transport, communications, financial services, business services, real estate, other private services, public administration, education, health

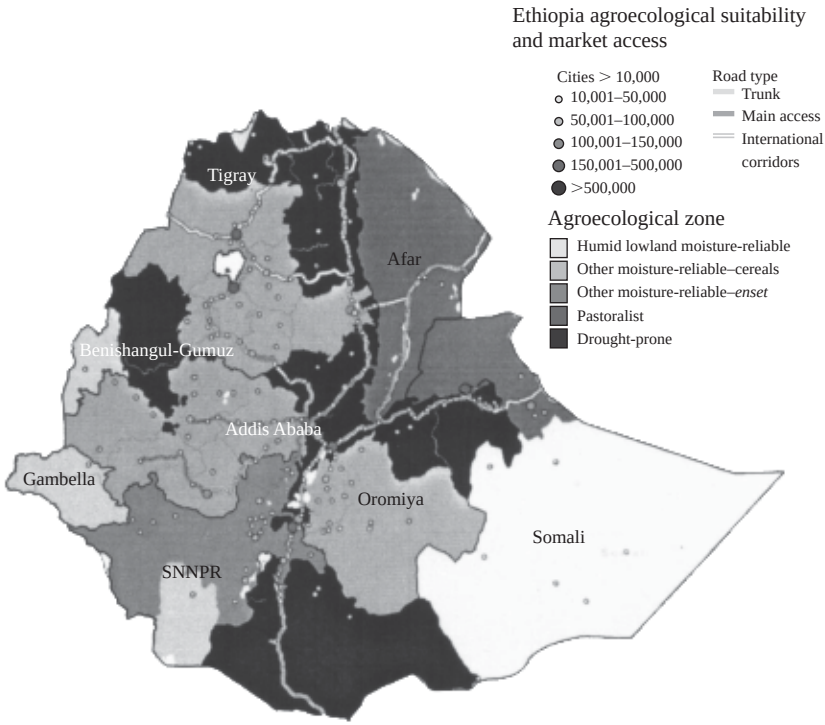
SOURCE: Dynamic Regional Economywide Model of Ethiopia (DREME).

To complete the agricultural sector, DREME has two further subsectors capturing forestry and fisheries. Most of the agricultural commodities listed are not only exported or consumed by households but are also used as inputs into various processing activities in the manufacturing sector. The agricultural processing sectors identified in the model range from meat, fish, and dairy to grain milling and sugar refining. The agricultural subsectors also use inputs from nonagricultural sectors, such as fertilizer from the fertilizer subsector and marketing services from the trade and transport subsectors.

DREME captures regional heterogeneity within Ethiopia. Farm production is disaggregated across four rural zones, as shown in Figure 8.1.These are Zone 1a ("humid lowland moisture-reliable" and "other moisture-reliable–cereals"), Zone 1b ("other moisture-reliable–*enset*"), Zone 2 ("drought-prone"), and Zone 3 ("pastoralist"). These zones reflect different agroecological and climatic conditions across the country.

DREME is calibrated to observed cropping patterns in each of the four zones. Representative farmers in each zone respond to changes in production technology and to commodity demand and prices by reallocating their land

FIGURE 8.1 Zones in the Dynamic Regional Economywide Model of Ethiopia (DREME), with city sizes, road types, and agroecological zones indicated, 2009



SOURCE: Ahmed et al. (2009).
NOTE: Zone 1a includes "humid lowland moisture-reliable" and "other moisture-reliable–cereals"; Zone 1b is "other moisture-reliable–*enset*"; Zone 2 is "drought-prone"; and Zone 3 is "pastoralist."

across different crops in order to maximize incomes. These farmers also reallocate their labor and capital between farm and nonfarm activities, including livestock and fishing, wage employment, and diversification into nonagricultural sectors, such as transport, trade, and construction. Thus, by capturing production information across subnational regions, DREME combines the national or macroeconomic consistency of an economywide model with zonal-level production models. DREME is thus an ideal tool for capturing the growth linkages and income and price effects resulting from accelerating growth in different agricultural sectors.

Finally, DREME endogenously estimates the impact of growth on household incomes and poverty. There are 12 representative household groups in the model, disaggregated by rural zones, small or large urban centers, and poor or nonpoor status. *Poor* is defined here as including all households falling into the

bottom two expenditure quintiles (that is, the poorest 40 percent of the population).[2] Household income elasticities are based on estimates from the 2004/05 Household Income, Consumption, and Expenditure Survey (HICES) (Ethiopia, CSA 2007; Table 8.2).[3]

Each household questioned in the 2004/05 HICES is directly linked to the corresponding representative household in the model. This is the microsimulation component of DREME. In this formulation of the model, changes in representative households' consumption and prices in the CGE model component are passed down to their corresponding households in the survey, where total consumption expenditures are recalculated. This new level of per capita expenditure for each survey household is compared to the separate poverty lines for rural and urban areas, and standard poverty measures are recalculated. Thus, poverty is measured in exactly the same way as in standard poverty estimates, and changes in poverty draw on the consumption patterns, income distribution, and poverty rates captured in the latest household income and expenditure survey.

Data Sources for the Model

The core dataset capturing the economic structure of the Ethiopian economy is the 2005/06 social accounting matrix (SAM) developed by the Ethiopian Development Research Institute (EDRI) (Ahmed et al. 2009). This SAM includes four agroecological zones and a detailed regional disaggregation of household groups. Zonal-level agricultural production and area data taken from the 2005/06 agricultural sample survey were used to identify the four zones and to disaggregate production in the SAM. DREME is therefore consistent with recent agricultural production levels and yields at the zonal level.

Poverty Reduction on Ethiopia's Current Growth Path

We use DREME to examine the impact of Ethiopia's current growth path on poverty reduction. This "business-as-usual" scenario draws on production trends for various agricultural and nonagricultural subsectors. Ethiopia experienced rapid growth from 1998 to 2007, with national GDP growing at almost 8 percent

2. Given this definition of poverty, we then use the cutoff level of per capita expenditures that defines poor and nonpoor households (separately for rural and urban areas) as the poverty line in the subsequent simulations.

3. The income elasticities in Chapter 7 are based on an estimated almost ideal demand system. We follow King and Byerlee (1978) instead because their approach is more consistent with the linear expenditure demand system in the DREME model. Moreover, as is evident from Table 8.2, we use stylized elasticities because the econometrically estimated results cannot always be used in our demand system (for example, negative "inferior good" elasticities cannot be used in the model). That said, the two sets of elasticities are broadly consistent and, over the short time frame of our analysis (10 years), are unlikely to greatly influence our conclusions. Finally, we choose to use these elasticities for consistency with the original analysis done as part of the CAADP review process.

TABLE 8.2 Selected income elasticities of goods and services in the Dynamic Regional Economywide Model of Ethiopia, by rural–urban place of residence, 2004/05

Good or service	Rural	Urban	Product or service	Rural	Urban
Maize	0.70	0.50	Cattle meat	0.80	0.80
Wheat	1.00	0.66	Poultry	0.75	1.15
Teff	1.10	0.70	Milk	0.75	0.75
Other cereals	0.70	0.50	Other meats	0.50	0.50
Root crops	0.50	0.70	Fish	0.70	0.70
Pulses	0.75	0.60	Processed foods	0.80	0.90
Oilseeds	0.80	0.50	Beverages	0.50	0.80
Enset	0.70	0.50	Textiles	1.20	1.00
Vegetables	0.50	0.75	Other manufactures	1.20	1.00
Fruits	0.50	0.75	Construction	0.90	0.50
Sugarcane	0.75	0.60	Utilities	1.00	0.80
Chat	0.70	0.50	Trade and transport	1.00	0.80
Coffee	0.60	0.60	Restaurants	0.80	0.50
Tobacco	0.70	0.50	Other private services	1.10	1.10
			Public services	1.20	0.90

SOURCE: Authors' estimates based on data from Ethiopia, CSA (2007).

per year. During this period the agricultural sector did not grow as rapidly, with an average growth rate of 6 percent per year. However, much of this rapid economic growth has occurred in the last few years, and it is uncertain whether such rapid growth can be achieved (and sustained) over the near term, especially in light of the global economic recession starting in 2009. Accordingly, the baseline scenario takes a more cautionary position and assumes average annual agricultural growth of 3.8 percent per year during 2009–15 (Table 8.3).[4] Although this is below the recent spike in agricultural GDP growth rates, it still assumes a fairly strong performance by the agricultural sector over the coming decade.[5]

More than half of agriculture's strong growth performance during 1998–2007 was driven by land expansion, with the rest resulting from changes in cropping patterns and improvements in yields. For example, the land area under

4. Simulations are run beginning with the base year, 2005/06. Productivity shocks are modeled only from 2008/09 onward, however (that is, all scenarios are the same until 2008/09), so simulation results are shown only from this year onward.

5. As discussed in more detail later, five different scenarios were designed for this analysis. Scenarios 1–3 target specific groups of crops or agricultural subsectors, including cereals (Simulation 1), export-oriented crops (Simulation 2), and livestock (Simulation 3). The all agriculture scenario (Simulation 4) includes additional growth from the fisheries and forestry subsectors. Simulation 5 includes accelerated productivity growth in the nonagriculture sector as well.

TABLE 8.3 Sector growth results from the model scenarios, 2009–15 (percent)

Sector	GDP share, 2009	Average annual GDP growth rate, 2009–15					
		Baseline (1)	Cereals (2)	Export crops (3)	Livestock (4)	All agriculture (5)	Nonagriculture (6)
Total GDP	100.00	5.95	6.26	6.39	6.81	6.88	6.88
Agriculture	44.90	3.81	4.57	4.87	5.81	5.98	4.14
Cereals	13.49	5.18	7.25	7.30	7.51	7.53	5.31
Pulses and oilseeds	3.83	3.34	3.54	3.60	3.75	3.77	4.06
Horticulture	2.45	3.84	3.96	4.01	4.08	4.26	3.88
Export crops	4.50	4.54	4.54	7.20	7.20	7.20	4.54
Other crops	3.66	3.79	4.07	3.94	3.96	3.97	5.15
Livestock	12.94	2.88	2.91	2.93	6.02	6.02	3.28
Other agriculture	4.04	1.51	1.52	1.52	1.52	3.52	1.52
Industry	12.47	7.27	7.27	7.28	7.36	7.36	8.73
Manufacturing	5.24	8.15	8.18	8.17	8.42	8.40	9.41
Agroprocessing	2.41	6.08	6.51	6.69	6.83	6.82	6.31
Other industry	1.89	6.93	6.99	7.05	7.18	7.16	7.75
Services	33.47	8.19	8.20	8.20	8.23	8.25	9.78
Private	11.76	6.80	6.91	7.03	7.16	7.20	8.10
Public	4.88	5.69	5.69	5.69	5.69	5.69	5.70

SOURCE: Results from the Dynamic Regional Economywide Model of Ethiopia (DREME).

NOTES: The simulations are cumulative, such that the export crop scenario (3) includes the productivity gains from the cereals scenario (2) plus additional productivity gains for export crops. Similarly, the livestock scenario (4) includes the productivity gains for both cereals and export crops (that is, from the previous two scenarios). GDP = gross domestic product.

maize cultivation expanded by 2.2 percent per year during this period, while yields improved each year by 1.5 percent. Similar patterns were observed for other cereals; the only exception was wheat, for which the land area expanded extremely fast, at 5.5 percent per year, compared to yield growth, at 2.7 percent. Long-term agricultural growth has thus been driven more by the expansion of cultivated land than by improvements in cropping technologies. The baseline scenario is calibrated to production trends from 1998 to 2007, so it assumes that land expansion will continue along its long-term path, with about two-thirds of production increases driven by area expansion. This is equivalent to an increase in total harvested land by 2.6 percent per year during 2009–15, which is slightly below the rural population growth rate of 3.0 percent. It is often argued that future land expansion possibilities in Ethiopia are fairly modest, yet recent production data do not suggest that this is the case (that is, that land is the dominant source of growth). In our analysis we assume that future land expansion will be slower than historical expansion. However, land's contribution to overall agricultural growth remains fairly constant because we assume equally modest yield growth.

According to production trends, land area expansion varies across zones. Cultivated land growth is 2.2 percent per year in Zones 1a and 1b (the humid regions), 3.2 percent in Zone 2 (the drought-prone region), and 3.7 percent in Zone 3 (the pastoralist region). As shown in Table 8.3, the nonagricultural sectors are expected to maintain their strong performance over the coming decade, with manufacturing and services growing more rapidly than agriculture, at 8.2 percent per year.

The 3.8 percent agricultural growth rate in the baseline scenario is based on more detailed production trends for different agricultural subsectors. Table 8.4 shows the assumptions made about each subsector's yield growth. We initially adopt the teff yield of 0.76 tons per hectare that was observed in 2005/06 and then assume that teff yields will grow at 2.86 percent per year, such that Ethiopia will achieve a sustained national average teff yield of 1.01 tons per hectare by 2015. The land area under teff cultivation will also grow at 2.33 percent each year in the baseline scenario, such that overall production will expand by 5.26 percent. This is consistent with observed production patterns for 1998–2007. Moreover, yield and area expansions vary at the zonal level based on actual production trends. The baseline thus reflects expected improvements in the performance of the teff sector over the next decade, with the rate of growth of investments continuing as before. Similarly, for wheat we assume that initial yields will continue to grow rapidly, at 3.40 per year, and that yields will rise to 1.67 tons per hectare by 2015. National and regional production of each of the five cereal crops in DREME is thus calibrated to closely reproduce long-term production trends.

National production trends were used to calibrate the baseline growth rates for noncereal crops. Particularly rapid production growth was observed for the

TABLE 8.4 Production targets for various crops in the baseline and agricultural growth scenarios, 2005–15

	Crop yields					Crop production					Crop land area	
	Levels (metric tons per hectare)			Growth rates (percent)		Levels (thousands of metric tons)			Growth rates (percent)		Growth rates (percent)	
Crop	Initial 2005	Baseline 2015	Target 2015	Baseline 2005–15	Target 2005–15	Initial 2005	Baseline 2015	Target 2015	Baseline 2005–15	Target 2005–15	Baseline 2005–15	Target 2005–15
Cereals												
Teff	0.76	1.01	1.11	2.86	3.81	2,191	3,660	4,011	5.26	6.23	2.33	2.34
Barley	1.00	1.30	1.50	2.63	4.13	1,271	2,009	2,260	4.68	5.93	2.00	1.72
Wheat	1.20	1.67	2.18	3.40	6.17	2,230	4,105	5,558	6.29	9.56	2.80	3.20
Maize	1.72	1.99	2.32	1.46	3.02	3,647	5,424	6,086	4.05	5.26	2.55	2.17
Sorghum	1.12	1.44	1.55	2.48	3.30	2,608	4,226	4,560	4.94	5.75	2.40	2.37
Pulses and oils												
Pulses	0.92	1.03	1.04	1.08	1.19	1,110	1,632	1,695	3.93	4.33	2.82	3.10
Oilseeds	0.77	0.76	0.78	–0.10	0.08	778	1,035	1,054	2.90	3.08	3.00	3.00

(*continued*)

TABLE 8.4 Continued

	Crop yields					Crop production					Crop land area	
	Levels (metric tons per hectare)			Growth rates (percent)		Levels (thousands of metric tons)			Growth rates (percent)		Growth rates (percent)	
Crop	Initial 2005	Baseline 2015	Target 2015	Baseline 2005–15	Target 2005–15	Initial 2005	Baseline 2015	Target 2015	Baseline 2005–15	Target 2005–15	Baseline 2005–15	Target 2005–15
Horticulture												
Enset	7.52	8.74	8.80	1.51	1.57	211	321	333	4.25	4.63	2.70	3.01
Vegetables	4.17	4.54	4.54	0.86	0.86	954	1,321	1,321	3.31	3.31	2.42	2.42
Fruits	13.73	15.78	15.78	1.40	1.40	436	630	630	3.74	3.74	2.31	2.31
Export crops												
Sugarcane	33.69	36.79	38.67	0.88	1.39	1,617	2,614	2,747	4.92	5.44	4.00	4.00
Tea	0.96	1.04	1.08	0.76	1.16	5	9	10	6.81	7.23	6.00	6.00
Cotton	1.01	1.07	1.25	0.58	2.13	86	135	157	4.61	6.21	4.00	4.00
Tobacco	0.67	0.64	0.74	–0.34	1.02	3	3	3	–1.33	0.01	–1.00	–1.00
Coffee	0.66	0.66	0.81	0.04	2.12	157	244	300	4.54	6.72	4.50	4.50
Flowers	1.00	1.10	1.21	1.00	1.91	10	13	15	3.02	3.95	2.00	2.00
Other crops												
Chat	0.77	0.79	0.79	0.19	0.19	120	165	165	3.24	3.24	3.05	3.05
Other staples	4.89	5.26	5.29	0.73	0.79	1,576	2,537	2,584	4.87	5.07	4.12	4.24
All crops											2.62	2.62

SOURCES: Crop targets are drawn from consultations with a Comprehensive Africa Agriculture Development Programme stocktaking team and representatives from the Ministry of Agriculture; final sector targets are based on results from the Dynamic Regional Economywide Model of Ethiopia (DREME).

NOTES: The growth rates shown are national averages. Baseline 2015 denotes levels in the baseline scenario for 2015. Baseline 2005–15 denotes the growth rate in the baseline scenario from 2005 to 2015.

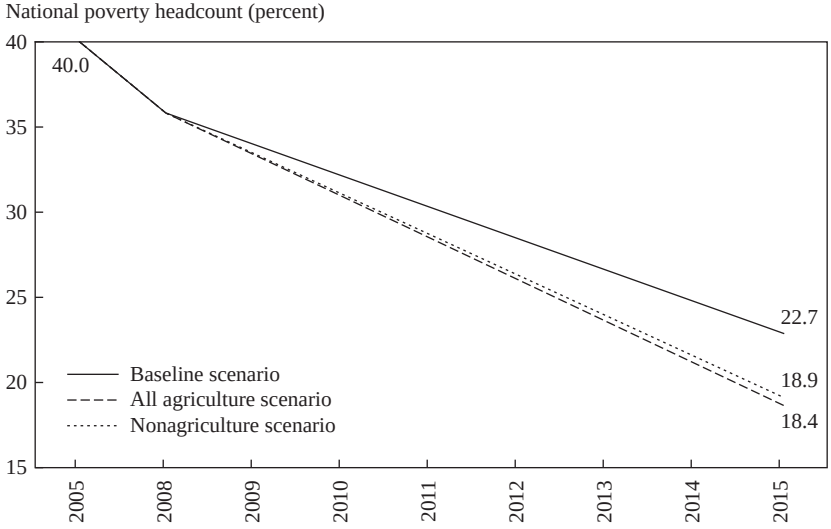
horticultural crops, including fruits, vegetables, and *enset*. However, unlike in the case of cereals, these high growth rates were driven more by land expansion than by improvements in crop yields. For example, during 1998–2007 *enset* yields remained largely unchanged, but cultivated land area grew extremely fast. This is reflected in the baseline scenario, where the production growth rate is driven mainly by a faster expansion of the *enset* land area. Similar biases toward land expansion over yield improvements were observed for pulses, oilseeds, and other staples such as root crops.

Industrial and export crops performed quite well during 1998–2007, with the exception of tobacco, whose production levels declined slightly. This is reflected in the baseline scenario. For example, coffee and cotton production will rise by 4.54 and 4.61 percent per year, respectively, during 2005–15, driven by a fairly rapid expansion of land area under export crop cultivation. The baseline scenario therefore assumes that the export-oriented crops will continue to grow rapidly, albeit more slowly than the major staple crops. Only tobacco production is expected to decline based on long-term trends.

Livestock is a key agricultural subsector generating a significant share of agricultural GDP, and it has strong upstream linkages to meat processing in the manufacturing sector (see Table 8.3). The baseline scenario assumes that livestock GDP will expand at a rate of 2.9 percent per year. This is below the rapid growth rate of the crop sectors but is entirely consistent with the livestock GDP growth rates reported in national accounts for 1998–2007. The baseline scenario reflects more rapid growth in the milk and poultry subsectors. Fisheries and forestry are also agricultural subsectors in DREME, with the latter generating 4.04 percent of total agricultural GDP in 2005/06. Based on national accounting for the period 1998–2007, the baseline scenario assumes that fisheries GDP will remain virtually unchanged during 2009–15. For the forestry subsector, the baseline scenario assumes that the value-added in this subsector will grow at 4.02 percent per year.

Drawing on the trends just described, DREME simulation results indicate that, with 4 percent growth in the agricultural sector and more rapid growth in the nonagricultural sectors, overall national GDP will grow at an average rate of 5.95 percent during 2009–15. This is equal to the average GDP growth rate of 6 percent observed for 1998–2007, thus assuming that Ethiopia's economy will maintain its long-term growth rate over the coming decade. With population growth at 3 percent per year, this means that per capita GDP will also grow rapidly, at about 3 percent. With rising per capita incomes and growth across all sectors, DREME estimates that poverty will decline from 40 percent to 23 percent during 2005–15 (see Figure 8.2). The faster expansion of the nonagricultural sectors means that national income growth favors urban households and areas more than rural ones. For example, poverty will fall in small urban centers from 34 to 9 percent by 2015, while rural poverty will decline from 41 to 25 percent. Given the overall rapid poverty reduction and despite an

FIGURE 8.2 National poverty headcount results from the model scenarios, 2005–15



SOURCE: Results from the Dynamic Regional Economywide Model of Ethiopia (DREME).
NOTES: The poverty headcount is the percentage of the population living below the poverty line. We assign the poverty line so that 40 percent of the population is classified as "poor" (that is, in the bottom two expenditure quintiles). As noted in footnote 4, all simulations are the same for 2005–08. Additional productivity shocks are modeled from 2009 onward.

expanding population, the absolute number of poor people in Ethiopia is expected to decline from 25.8 million people in 2005 to 19.6 million by 2015. Although this will be a significant reduction in the number of poor people living in Ethiopia, it reveals the persistent burden of poverty in the country and emphasizes the need to reinforce pro-poor sources of economic growth.

Accelerating Agricultural Growth and Poverty Reduction

In the previous section we described the results of the baseline scenario, which estimated the impact of Ethiopia's current growth path on poverty reduction. We found that while economic growth over the coming decade is expected to remain robust and will halve the national poverty rate by 2015, it will reduce the number of poor people by less than one-third. Therefore, in this section we examine whether a medium-term 6 percent agricultural growth target identified by the CAADP is attainable based on reasonable subsector growth potentials. We also estimate the potential contribution of individual agricultural subsectors in helping Ethiopia substantially reduce poverty throughout the country.

Examining Whether a Sustained 6 Percent Agricultural Growth Rate Is Attainable

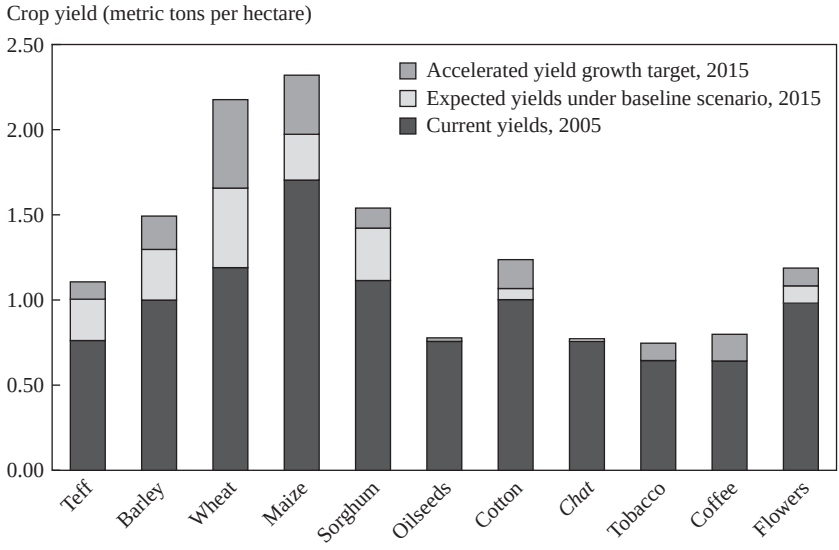
Accelerated crop production is modeled by increasing yields in order to achieve the ambitious yield targets identified for 2015. We do not attempt to identify the specific investments needed to achieve these yield targets; this is a topic addressed in other chapters. Our analysis merely translates yield projections into agricultural and national economic growth and into reductions in poverty. Our goal is to identify which potential sources of agricultural growth would be most effective in assisting Ethiopia achieve its broader development objectives.

Taking teff as an example, in the baseline scenario we assumed that average yields would rise from 0.76 to 1.01 tons per hectare during 2006–15 (see Table 8.4). In this section we model more ambitious teff yield improvements, with the annual yield growth rate for teff rising from its current 2.86 percent per year to 3.82 percent per year. This implies that national average teff yields will rise consistently over the next decade to reach 1.11 tons per hectare by 2015. This national target yield was identified together with the CAADP stocktaking team and in consultation with the Ministry of Agriculture and Rural Development. The yields of other crops were also increased in a similar manner but to differing degrees based on long-term trends and potential yields (Figure 8.3). Production growth targets were also identified for the livestock and fisheries subsectors.

Five different scenarios were designed for this analysis (see Table 8.3). In Scenarios 1–3 we target specific groups of crops or agricultural subsectors, including cereals (Simulation 1), export-oriented crops (Simulation 2), and livestock (Simulation 3). For instance, in the "cereal-led growth" scenario we increase total factor productivity (TFP) for all cereal crops so as to achieve the crop-specific yield target shown in Table 8.4. In the noncrop scenarios, such as "livestock-led growth," we also increase TFP of the particular noncrop sector to achieve targeted GDP growth rates. The results of each simulation are cumulative, so that Simulation 2 includes the effects of Simulation 1, Simulation 3 includes the effects of Simulation 2, and so on. In the "all agriculture" scenario (Simulation 4) we include additional growth from the fisheries and forestry subsectors. This is equivalent to a "CAADP scenario," because it captures all possible sources of additional agricultural growth.

In the all agriculture scenario, agricultural growth accelerates to 6 percent per year for 2009–15 (see Table 8.3). This is driven by a strong expansion in cereal production. For example, wheat production increases from about 4 million tons in the baseline scenario to over 6 million tons in the all agriculture scenario (see Table 8.4). A similarly large expansion of coffee production is also achieved in this accelerated scenario. Thus, even though the additional growth required for other crops is less pronounced, the achievement of the

FIGURE 8.3 Current, expected, and targeted crop yields, 2005 and 2015



SOURCES: Crop targets are drawn from consultations with a stocktaking team from the Comprehensive Africa Agriculture Development Programme and representatives from the Ministry of Agriculture; final sector targets are based on results from the Dynamic Regional Economywide Model of Ethiopia (DREME).

6 percent agricultural growth target remains ambitious. Livestock growth will also have to double, from an annual average growth rate of 2.88 percent per year in the baseline scenario to 6.02 percent in the all agriculture scenario. However, despite these challenges, the results from DREME indicate that if the crop yield and livestock productivity targets can be achieved by 2015, Ethiopia will be able to achieve and sustain the 6 percent agricultural growth target set forth by the CAADP.

Because agriculture represents more than a third of the Ethiopian economy, the acceleration of agricultural growth will increase the national GDP growth rate from its current 5.95 percent per year to 6.88 percent per year. Faster agricultural growth will also stimulate additional growth in the nonagricultural sectors by raising the final demand for nonagricultural goods and by lowering input prices and fostering upstream processing. For instance, in the all agriculture scenario the GDP growth rate of agriculture processing in the manufacturing sector increases from 6.08 percent in the baseline scenario to 6.82 percent per year. Achieving the 6 percent agricultural growth target therefore has economywide growth linkage effects for nonagriculture.

Looking at Whether Agricultural Growth Reduces Poverty

The acceleration of agricultural growth to around 6 percent per year in the all agriculture scenario and its spillover effects into nonagriculture will cause poverty to decline by a further 4.3 percentage points. This is shown in Figure 8.2, where the share of Ethiopia's population under the poverty line falls to 18.36 percent by 2015 in the all agriculture scenario compared to 22.67 percent in the baseline scenario. Thus, taking population growth into account, achieving the 6 percent growth target will lift an additional 3.7 million people above the poverty line by 2015. This is sufficient to almost halve the number of poor people in Ethiopia today (that is, reducing their numbers from 25.8 million to 15.9 million).

Faster agricultural growth will benefit a majority of households. However, not all households in all agroecological zones will benefit equally from achieving the higher crop yields and faster subsector growth rates targeted in the all agriculture growth scenario. Table 8.5 shows how poverty rates change under the various scenarios. Poverty declines among both rural and urban households, although the declines are more than twice as large in rural areas. Moreover, there are large declines in rural poverty rates in the two zones in which poverty is initially highest: the humid *enset* region (Zone 1b) and the drought-prone region (Zone 2). In urban areas, households in both small and large urban centers benefit from faster agricultural growth. This is because urban households usually spend a significant share of their incomes on food and agricultural products. They thus benefit from faster agricultural growth and lower food prices.

The impact of agricultural growth on households' incomes and poverty depends on a number of factors. One key factor is the geographic distribution of agricultural production. As indicated in Table 8.6, higher-value export-oriented crops are grown more intensively in certain zones.[6] Coffee, for example, is concentrated in the humid cereal region (Zone 1a). However, it forms a large share of agricultural GDP in the humid *enset* region (Zone 1b). Similarly, although cereals form a large share of agricultural GDP in the humid cereal region (Zone 1a), they also contribute a large share to the poorer drought-prone region's agricultural GDP (that is, they have a 41.8 percent share in Zone 1a and a 34.1 percent share in Zone 2). Finally, livestock is a key sector in all regions, contributing between one-fourth and one-third to agricultural GDP in Zones 1a, 1b, and 2. However, it is especially important in the pastoralist region, where it accounts for most of agricultural GDP, with the remaining agricultural incomes dominated by cereals. These concentrations of particular crops and

6. Note that in Table 8.5 agricultural GDP excludes fisheries and forestry (that is, it includes only crops and livestock).

TABLE 8.5 Household poverty results for rural and urban regions from the model scenarios, 2005, 2008, and 2015 (percent)

Region (zone number)	Initial poverty headcount		Final year poverty headcount, 2015					
	2005	2008	Baseline (1)	Cereals (2)	Export crops (3)	Livestock (4)	All agriculture (5)	Nonagriculture (6)
National	40.00	35.88	22.67	20.28	19.36	18.38	18.36	18.88
Rural regions	41.33	37.28	25.49	22.80	21.80	20.82	20.77	20.96
Humid cereals (1a)	38.19	33.91	20.71	18.48	17.65	17.35	17.35	17.11
Humid *enset* (1b)	44.98	41.05	30.15	27.66	26.26	24.83	24.41	23.91
Drought–prone (2)	47.97	44.14	33.13	29.43	28.31	26.92	27.08	27.74
Pastoralist (3)	27.70	24.11	16.10	13.45	12.91	10.19	10.19	13.69
Small urban centers	33.95	28.94	8.57	7.55	7.10	6.20	6.41	7.67
Large urban centers	32.95	29.16	9.30	8.48	7.84	6.75	6.77	10.48

SOURCE: Results from the Dynamic Regional Economywide Model of Ethiopia (DREME).

NOTES: The poverty headcount is the percentage of the population living below the poverty line. We assign the poverty line so that 40 percent of the population is classified as poor (that is, in the bottom two expenditure quintiles).

TABLE 8.6 Regional growth results for various crops under the model scenarios, 2009–15 (percent)

Zone (zone number), crop	Initial agricultural GDP share	Average annual GDP growth rate, 2009–15					
		Baseline (1)	Cereals (2)	Export crops (3)	Livestock (4)	All agriculture (5)	Nonagriculture (6)
Humid cereals (1a)							
Agriculture	100.00	4.05	5.15	5.50	6.31	6.33	4.33
Cereals	41.77	5.19	7.54	7.58	7.79	7.81	5.32
Pulses and oils	12.17	2.90	2.96	3.03	3.17	3.19	3.62
Horticulture	4.18	2.94	2.85	2.86	2.89	3.08	2.98
Export crops	9.88	4.55	4.55	7.55	7.55	7.55	4.55
Other staples	3.60	2.97	3.07	3.11	3.17	3.18	3.95
Livestock	28.39	2.88	2.92	2.93	5.63	5.64	3.29
Humid *enset* (1b)							
Agriculture	100.00	3.70	4.16	4.85	5.45	5.48	4.18
Cereals	17.57	2.75	4.77	4.88	5.08	5.10	2.88
Pulses and oils	4.81	4.49	4.95	4.96	5.18	5.21	5.41
Horticulture	13.46	4.15	4.35	4.43	4.54	4.71	4.19
Export crops	22.43	4.52	4.52	7.37	7.37	7.37	4.52
Other staples	21.12	3.89	4.13	3.93	3.97	3.97	5.36
Livestock	20.61	2.87	2.91	2.92	5.64	5.65	3.28

(*continued*)

TABLE 8.6 Continued

Zone (zone number), crop	Initial agricultural GDP share	Average annual GDP growth rate, 2009–15					
		Baseline (1)	Cereals (2)	Export crops (3)	Livestock (4)	All agriculture (5)	Nonagriculture (6)
Drought-prone (2)							
Agriculture	100.00	4.42	5.13	5.33	6.09	6.11	4.83
Cereals	34.07	5.79	7.36	7.41	7.63	7.64	5.91
Pulses and oils	9.41	3.95	4.35	4.43	4.57	4.59	4.63
Horticulture	6.51	4.41	4.68	4.73	4.80	4.98	4.48
Export crops	9.69	4.53	4.53	6.40	6.40	6.40	4.53
Other staples	13.50	4.07	4.45	4.31	4.30	4.31	5.49
Livestock	26.81	2.87	2.91	2.92	5.61	5.62	3.28
Pastoralist (3)							
Agriculture	100.00	2.91	2.93	2.95	7.17	7.18	3.32
Cereals	2.37	3.31	2.54	2.61	2.77	2.78	3.44
Pulses and oils	0.06	5.77	7.12	7.07	7.23	7.24	6.82
Horticulture	0.56	4.25	4.25	4.25	4.25	4.46	4.25
Export crops	0.14	4.67	4.67	4.67	4.67	4.67	5.76
Other staples	1.38	3.86	3.86	3.86	3.86	3.86	4.95
Livestock	95.49	2.88	2.91	2.93	7.33	7.33	3.28

SOURCE: Results from the Dynamic Regional Economywide Model of Ethiopia (DREME).

NOTE: GDP = gross domestic product. In this table agricultural GDP excludes fisheries and forestry because these two sectors are not regionalized in DREME.

subsectors will influence how agricultural growth driven by certain sectors affects household incomes in different parts of the country.

The sources of additional income also vary across representative households within zones. Not surprisingly, households that already depend on cereals tend to benefit more from cereal-led growth. However, two forces drive changes in production following subsector-specific yield improvements. First, increasing cereal yields directly affect farm incomes because they increase the quantity of output that a farm produces using the same quantity of factor inputs. But because supply of the agricultural product increases faster than demand (unless incomes are rising rapidly from other sources), prices typically fall following yield increases. In response to these price changes, farmers may reallocate some of their land to other crops. Thus, it is important to note that, although we model cereal-led growth by increasing cereal yields, some of the gains in this scenario are derived from diversification into other higher-value crops facing better demand conditions. DREME captures both direct and indirect effects in its assessment of the effects of improved yields in different subsectors.

Real income and poverty impacts are also determined by household consumption demand. For example, households that spend a significant share of their incomes on cereals will benefit from lower prices when cereal production rises. Household consumption patterns are based on the 2004/05 HICES, as captured in EDRI's 2005/06 SAM. The average budget shares for different household groups are shown in Table 8.7. Even though relatively little agricultural GDP in the pastoralist region (Zone 3) is derived from cereal production, households in this region spend 16 percent of their disposable income on cereals. Thus, although a national expansion of cereal production may not directly benefit households in the pastoralist region, it will indirectly benefit them through lower food prices. This is also the case for urban households, which derive relatively little income from agriculture directly but spend at least a third of their incomes on agricultural goods and processed foods. Together with regional production patterns, these average budget shares and the income elasticities in Table 8.2 will determine the impact of agricultural growth on poverty.

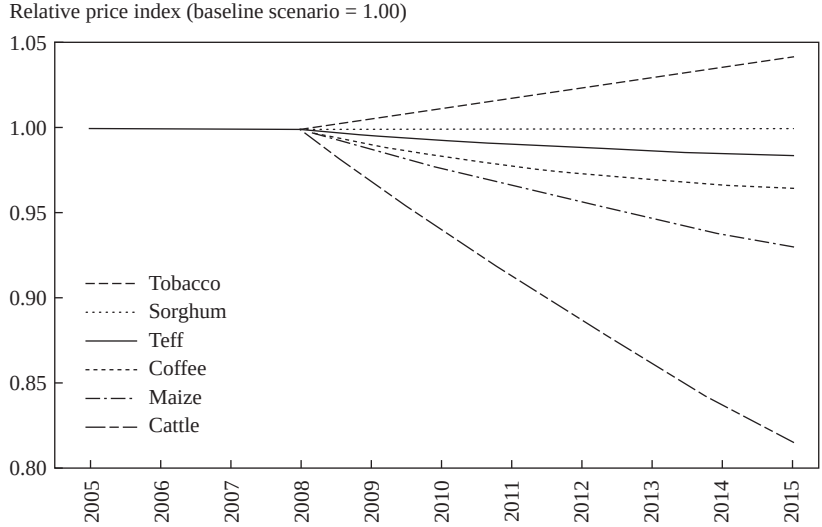
Figure 8.4 shows the importance of taking demand constraints and relative price changes into account. Wheat, for example, faces domestic demand constraints and has weaker linkages to upstream food processing and foreign markets. Therefore, when wheat production increases substantially in the all agriculture scenario, its prices decline by 7 percent in real terms (or relative to the overall consumer price index). Milk and cattle product prices decline more sharply (by more than 15 percent), highlighting the crucial importance of improved marketing in these subsectors. By contrast, some agricultural subsectors, such as pulses and horticulture, do not experience yield improvements in the all agriculture scenario, so increased household incomes cause real prices for these crops to rise. Finally, some crops, such as coffee, may also have stronger

TABLE 8.7 Household average consumption shares of various goods and services, by rural–urban place of residence and poverty status, 2009 (percent)

	Rural households							Urban households				
Good or service	All	Zone 1a	Zone 1b	Zone 2	Zone 3	Poor	Nonpoor	All	Small centers	Large centers	Poor	Nonpoor
All goods and services	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Agriculture	53.7	53.4	47.1	57.1	56.8	59.3	51.1	26.9	31.1	21.8	42.4	22.6
Cereals	20.5	23.1	13.1	21.8	15.8	24.6	18.6	8.6	10.1	6.9	16.3	6.5
Pulses and oilseeds	4.2	5.0	2.7	4.5	1.4	4.8	4.0	1.6	1.8	1.3	2.9	1.2
Horticulture	3.6	2.5	7.5	3.5	0.5	3.9	3.5	1.3	1.5	1.0	2.2	1.0
Export crops	2.6	2.8	3.7	1.9	1.3	2.9	2.5	1.2	1.5	0.8	2.0	1.0
Other crops	5.8	4.8	5.4	7.4	5.8	5.9	5.8	3.3	3.9	2.6	5.2	2.8
Livestock	10.6	9.1	6.8	11.6	28.3	11.6	10.1	8.6	9.0	8.1	10.4	8.1
Other agriculture	6.3	6.0	7.8	6.4	3.6	5.6	6.7	2.4	3.4	1.1	3.3	2.1
Industry	25.7	24.1	30.9	24.3	29.4	21.7	27.6	44.7	41.4	48.8	36.2	47.1
Manufacturing	24.9	23.4	30.3	23.3	28.6	20.8	26.8	41.2	39.0	43.8	33.5	43.3
Agroprocessing	12.2	11.7	14.2	11.3	15.2	11.2	12.7	16.1	16.7	15.4	19.1	15.3
Other industry	0.8	0.7	0.6	1.0	0.8	0.8	0.8	3.5	2.4	4.9	2.8	3.8
Services	20.6	22.5	21.9	18.6	13.8	19.0	21.4	28.4	27.5	29.4	21.4	30.3

SOURCE: Ethiopian Development Research Institute social accounting matrix (Ahmed et al. 2009).

FIGURE 8.4 Changes in real market prices from the baseline under the "all agriculture" scenario, 2005–15



SOURCE: Results from the Dynamic Regional Economywide Model of Ethiopia (DREME).
NOTE: These are real price changes for selected products relative to the prices achieved under the baseline scenario (adjusted for changes in the overall consumer price index). They therefore show how additional production places downward pressure on some commodities' prices, but rising incomes and demand allow some commodities' prices to rise when growth is accelerated.

linkages to upstream processing and foreign markets, which means that their prices are quite stable, even in the all agriculture scenario.

Exploring the Effectiveness of Nonagricultural Growth in Reducing Poverty

In the "nonagriculture" scenario (Simulation 5), we accelerate productivity growth in only the nonagriculture-related sectors such that the same rate of total GDP growth (that is, 6.88 percent per year) is achieved as in the all agriculture scenario. This is shown in Table 8.3. Faster nonagricultural growth stimulates the demand for agriculture, helping raise agriculture's GDP growth, albeit only slightly. Within the agricultural sector, the increase in demand for agricultural products is greater for cereals and livestock, which form a larger share of the consumption baskets of urban households and nonagricultural workers, whose incomes are rising as a result of faster nonagricultural growth.

Nonagricultural growth is also effective in reducing poverty. Given that the same total GDP growth rate is achieved in both the all agriculture and the nonagriculture scenarios, the national poverty headcount rate declines only

slightly less when growth is nonagriculture led (see Figure 8.2). Although the production linkages mentioned earlier are one reason for nonagriculture's poverty effect, another reason is that the marketing and demand constraints facing rapid increases in agricultural production are partially relieved by faster income growth outside of agriculture.

In summary, DREME results indicate that the CAADP agricultural growth target of 6 percent is ambitious. It will require substantial improvements in crop yields and livestock productivity over a relatively short period of time (that is, seven years). If these crop- and subsector-level targets can be achieved, the resulting broader-based agricultural growth is likely to benefit households in both rural and urban areas. However, the higher growth potential of certain export crops and better market conditions in certain parts of the country may cause uneven income growth and poverty reduction. The livestock subsectors also contribute to agricultural growth and poverty reduction throughout the country. Finally, accelerating nonagricultural growth can take advantage of production linkages while also reducing some of the demand constraints on agricultural growth. An agriculture-led growth strategy therefore needs to be supported by growth in other sectors if it is to be sustainable and achieve the greatest possible poverty reduction.

Comparing Subsector Growth in Terms of Growth and Poverty Reduction

The previous section highlighted the potential contributions of different crops and subsectors in increasing agricultural growth and poverty reduction. However, the different sizes of these subsectors make it difficult to compare the effectiveness of sector growth in reducing poverty. Understanding how growth–poverty linkages vary at the subsector and household levels is important in designing pro-poor growth strategies in different parts of the country. In this section, we calculate poverty–growth elasticities that allow us to compare the "pro-poorness" of growth in alternative subsectors. These elasticities are endogenous outcomes from the model results. Growth affects individual households differently due to heterogeneity across household groups. The previous analysis has shown how, with differences in household and farm characteristics, changes in income and consumption across households can differ considerably from average changes at the national level. Thus, to capture growth–poverty linkages, changes in the distribution of incomes, which are primarily determined by a country's initial conditions, need to be understood. In the previous section, we saw how households in certain regions have better opportunities to produce export-oriented crops and are thus better positioned to benefit from export crop–led agricultural growth. However, export crop–producing households are typically less poor than other rural households. Thus, agricultural growth driven by export crops may have less of an impact on poverty, especially among the poorest households. By contrast, the cereals sector tends to be a more important

source of agricultural incomes for poorer households. Thus, growth in cereals may be more effective in reducing poverty than is similar growth in export crops.

"Poverty–growth elasticities" measure the responsiveness of the poverty rate to changes in per capita agricultural GDP growth. More specifically, elasticity measures the percentage change in the poverty rate caused by a 1 percent increase in agricultural GDP per capita. Table 8.8 shows the calculated poverty–growth elasticities in the different growth scenarios. The results indicate that agricultural growth driven by cereals is particularly effective in reducing poverty in the drier regions (Zones 2 and 3), where households are generally poorer and depend more heavily on incomes from cereal production. Poverty in the pastoralist region (Zone 3) is also greatly affected by cereal-led growth due to the importance of these crops in poorer households' consumption baskets (see Table 8.7). For a similar reason, cereal-led growth is also effective in reducing poverty in smaller urban centers, where households are poorer than in larger centers and thus spend a larger share of their incomes on purchasing cereals and milled grains.

In contrast, expanding export crops is most effective in reducing poverty in the humid *enset* region (Zone 1b) and among households in larger urban centers, who are better endowed with capital and the other assets needed to produce export crops. Finally, livestock production is especially effective in reducing poverty in urban areas and among rural households in the pastoralist region (Zone 3). Urban consumers spend a larger share of their incomes on meat and dairy products and so benefit more when production in this sector expands

TABLE 8.8 Poverty–growth elasticities from the model scenarios: Percentage change in the poverty headcount rate from a 1 percent increase in national agricultural GDP, by rural–urban place of residence and sector, 2009–15

Rural zone (zone number), urban center	Sector		
	Cereal-led	Export crops–led	Livestock-led
National	–1.17	–1.08	–0.36
Rural zone	–1.27	–1.13	–0.35
Humid cereals (1a)	–1.16	–1.03	–0.12
Humid *enset* (1b)	–1.06	–1.44	–0.46
Drought-prone (2)	–1.48	–1.06	–0.42
Pastoralist (3)	–1.94	–0.93	–1.50
Small urban centers	–0.62	–0.65	–0.42
Large urban centers	–0.50	–0.92	–0.50

SOURCE: Results from the Dynamic Regional Economywide Model of Ethiopia (DREME).

NOTES: The poverty headcount is the percentage of the population living below the poverty line. We assign the poverty line so that 40 percent of the population is classified as poor (that is, in the bottom two expenditure quintiles). GDP = gross national product.

(see Table 8.7). Overall, however, it is the cereals sector that is most effective in reducing national poverty, because a larger share of poor households depend on cereals for their incomes and because more poor consumers (in rural and urban areas) spend a greater share of their income on cereals and milled grains.

The previous section concluded that to increase agricultural growth and reach the 6 percent growth target, it will be necessary to encourage growth in a number of agricultural subsectors. The poverty–growth elasticities suggest that cereals should be afforded a high priority in any strategy aimed at substantially reducing poverty. Moreover, cereals already form a large part of the agricultural sector and have high enough growth potential to substantially raise agricultural and national GDP. Cereals are therefore a priority sector for increasing investments.

Conclusions

A new economywide modeling framework was developed and used to examine the contribution of accelerating growth in alternative agricultural crops and subsectors and to assess how Ethiopia can achieve the CAADP target of 6 percent agricultural growth. The impact of agricultural growth at the macro- and microeconomic levels, as well as its effect on poverty, was estimated. The four major conclusions of this chapter are summarized here.

Six Percent Agricultural Growth Is Ambitious but Not Unattainable

The CGE model results indicated that if Ethiopia can meet its targets for crop yields and livestock productivity, it should be able to reach and sustain the 6 percent agricultural growth target during 2006–15. Even though these yield targets are below the maximum potential yields identified by agricultural field trials, they are still ambitious given the short time frame of the CAADP initiative (that is, seven years). However, agricultural growth of 6 percent per year would increase overall GDP growth by 1 percentage point per year. This higher growth rate would reduce national poverty to 18.36 percent by 2015, which is lower than the 22.67 percent poverty rate that would have been achieved without additional agricultural growth. This means that the higher rate of growth in the accelerated agricultural growth scenario would lift an additional 3.7 million people above the poverty line by 2015.

Not Everyone Will Benefit Equally in the CAADP Growth Scenario

Most households are expected to benefit from faster agricultural growth. However, some agroecological zones that grow higher-value cereals and export-oriented crops and are better situated with regard to larger urban markets (for example, the rain-sufficient highlands) stand to gain more than other parts of the country. Furthermore, poverty among households in some zones will remain high, despite faster agricultural growth. Finally, both rural and urban house-

holds benefit from faster agricultural growth, although rural households benefit more. This is because agricultural incomes are most important for rural households, but food commodities are an important part of the consumption baskets of both urban and rural households.

The Composition of Agricultural Growth Matters

Comparing the effectiveness of growth driven by different subsectors in reducing poverty and encouraging broader-based growth, we find that additional growth driven by cereals has a greater impact on poverty reduction, especially in rural areas. This is because these crops already demonstrate strong growth and so can contribute substantially to achieving broad-based agricultural growth. Yield improvements in these crops not only benefit households directly, by increasing incomes from agricultural production, but also allow farmers to diversify their land allocation toward other higher-value crops. Cereals are also effective in raising rural real incomes and reducing poverty, especially among the poorest households. Thus, high priority should be afforded to improving cereal yields and opening market opportunities for upstream processing to reduce demand constraints.

Nonagricultural Growth Is Also Effective in Reducing Poverty

Finally, although our analysis focused on agriculture, we also considered the effectiveness of nonagricultural growth in driving poverty reduction and economywide growth. We found that nonagriculture has a crucial role to play in helping overcome the demand constraints that hinder agricultural development. Therefore, even though Ethiopia's development strategy is centered on agriculture, high nonagricultural growth (in excess of the usual growth linkage effects emanating from agricultural growth) is required to boost demand for agricultural products if an agriculture-led strategy is to be both successful and sustainable.

Appendix: Specification of the CGE and Microsimulation Model

DREME is the name of the CGE model that was developed to assess sector-specific growth options and their poverty impacts (see Table 8A.1 at the end of this appendix for the model sets, parameters, and variables and Table 8A.2 for the model equations). The model is calibrated to EDRI's 2005/06 SAM, which provides information on demand and production for 69 detailed sectors (see Table 8.1).[7] The model further disaggregates agricultural activities across agroecological regions using data from the 2005 agricultural sample survey. Based on the SAM, the production technologies across all sectors are calibrated to

7. The model is a variant of the basic neoclassical CGE model developed by Dervis, de Melo, and Robinson (1982) and Lofgren, Harris, and Robinson (2001).

their current situation, including each sector's use of primary inputs, such as land, labor, and capital, as well as intermediate inputs. To capture existing differences in labor markets, the model classifies employed labor into different subcategories, including skilled, semiskilled, and unskilled workers, based on occupational categories. Information on employment and wages by sector and region is taken from the 2004/05 HICES (Ethiopia, CSA 2007).

Most workers in the model can migrate between regions and sectors. These workers are disaggregated according to occupational categories (that is, administrators; professional, skilled, and unskilled workers). Agricultural family labor is region specific but mobile across agricultural subsectors. Both agricultural and nonagricultural capital investments move freely across regions and within the broad nonagriculture sector. Capital is accumulated through investment financed by domestic savings and foreign inflows. Increased capital is allocated across sectors and regions according to their relative profitability. Once invested, capital becomes sector specific and can be adjusted only through exogenously determined depreciation and the attraction of new investments. Incomes from employment accrue to households according to employment and wage data from the HICES. This detailed specification of production and factor markets in the model allows it to capture the changing scale and technology of production across sectors and subnational regions and therefore how changes in the economic structure of growth influence its distribution of incomes.

The growth–poverty relationship is examined by combining DREME with a microsimulation model. An important factor determining the contribution of agriculture to overall economic growth is its linkages with the rest of the economy. Agriculture's proponents argue that agriculture has strong growth linkages. The model captures production linkages by explicitly defining a set of nested constant elasticity of substitution (CES) production functions that allows producers to generate demand for both factors and intermediates. DREME also captures forward and backward production linkages between sectors. Import competition and export opportunities are modeled by allowing producers and consumers to shift between domestic and foreign markets depending on changes in the relative prices of imports, exports, and domestic goods. More specifically, the decision of producers to supply domestic or foreign markets is governed by a constant elasticity of transformation function, while there are possibilities for substitution between imports and domestically supplied goods under a CES Armington specification. In this way the model captures how import competition and the changing export opportunities of agriculture and industry can strengthen or weaken the linkages between growth and poverty.

Incomes from production, trade, and employment accrue to different households according to employment and wage data from the HICES. As in the case of production, households are defined at the regional level and, within each region, by rural and urban areas and by poor and nonpoor categories. Poverty

is defined as being in the bottom two quintiles of per capita expenditure. Income and expenditure patterns vary considerably across these household groups. These differences are important for distributional change because incomes generated by agricultural growth accrue to different households depending on their location and factor endowments. Each representative household in the model is an aggregation of a group of households in the HICES. Households in the model receive income through the employment of their factors in both agricultural and nonagricultural production; they then pay taxes, save, and make transfers to other households. The disposable income of a representative household is allocated to commodity consumption derived from a Stone–Geary utility function (that is, a linear expenditure system of demand). In order to retain as much information on households' income and expenditure patterns as possible, DREME is linked to a microsimulation module based on the HICES. Endogenous changes in commodity consumption for each aggregate household in the CGE model are used to adjust the level of commodity expenditure of the corresponding households in the survey. Real consumption levels are then recalculated in the survey, and standard poverty measures are estimated using this updated expenditure measure.

DREME makes a number of assumptions about how the economy maintains macroeconomic balance. These "closure rules" concern the foreign or current account, the government or public-sector account, and the savings–investment account. For the current account, a flexible exchange rate maintains a fixed level of foreign savings. This assumption implies that the country cannot simply increase its foreign debt but has to generate export earnings in order to pay for imported goods and services. While this assumption realistically limits the degree of import competition in the domestic market, it also underlines the importance of the agricultural and industrial export sectors. For the government account, tax rates and real consumption expenditure are exogenously determined, leaving the fiscal deficit to adjust to ensure that public expenditures equal receipts. For the savings–investment account, real investment adjusts to changes in savings (that is, savings-driven investment). These two assumptions allow the models to capture the effects of growth on the level of public investment and the crowding-out effect from changes in government revenues.

Finally, DREME is recursive dynamic, which means that some exogenous stock variables in the model are updated each period based on intertemporal behavior and results from previous periods. The model is run over the period 2005–15, with each equilibrium period representing a single year. It also exogenously captures demographic and technological change, including changes in population, labor supply, human capital, and factor-specific productivity. Capital accumulation occurs through endogenous linkages with previous-period investment. Although the allocation of newly invested capital is influenced by each sector's initial share of gross operating surplus, the final allocation depends

on depreciation and sector profit rate differentials. Sectors with above-average returns in the previous period receive a larger share of the new capital stock in the current period.

In summary, DREME incorporates distributional change by (1) disaggregating growth across subnational regions and sectors, (2) capturing income effects through factor markets and price effects through commodity markets, and (3) translating these two effects for each household in the HICES according to its unique factor endowment and income and expenditure patterns. The structure of the growth–poverty relationship is therefore defined explicitly ex ante based on observed country-specific structures and behavior. This allows the model to capture the poverty and distributional changes associated with agricultural growth.

For the simulations of agricultural productivity gains presented in this chapter, total factor productivity growth in specified crop, livestock, or industrial sectors is exogenously increased according to the structure of each particular simulation. The productivity shock simulations are cumulative, with each successive simulation including the productivity shocks from the earlier simulations. Thus, for example, the export crop scenario (Simulation 2) includes the productivity gains from the cereals scenario (Simulation 1) plus additional productivity gains for export crops. Similarly, the livestock scenario (Simulation 3) includes the productivity gains for both cereals and export crops (Simulation 2) plus additional productivity gains in the livestock sector. As noted in footnote 4, all simulations use the same productivity growth rates for all sectors from 2005 to 2008. The productivity shocks differ across simulations only from 2009 onward.

TABLE 8A.1 Computable general equilibrium model sets, parameters, and variables

Symbol	Explanation	Symbol	Explanation
Sets			
$a \in A$	Activities	$c \in CMN\ (\subset C)$	Commodities not in *CM*
$a \in ALEO\ (\subset A)$	Activities with a Leontief function at the top of the technology nest	$c \in CT\ (\subset C)$	Transaction service commodities
		$c \in CX\ (\subset C)$	Commodities with domestic production
$c \in C$	Commodities	$f \in F$	Factors
$c \in CD\ (\subset C)$	Commodities with domestic sales of domestic output	$i \in INS$	Institutions (domestic and rest of world)
$c \in CDN\ (\subset C)$	Commodities not in *CD*	$i \in INSD\ (\subset INS)$	Domestic institutions
$c \in CE\ (\subset C)$	Exported commodities	$i \in INSDNG\ (\subset INSD)$	Domestic nongovernment institutions
$c \in CEN\ (\subset C)$	Commodities not in *CE*	$h \in H\ (\subset INSDNG)$	Households
$c \in CM\ (\subset C)$	Aggregate imported commodities		
Parameters			
$cwts_c$	Weight of commodity *c* in the consumer price index	pwm_c	Import price (foreign currency)
$dwts_c$	Weight of commodity *c* in the producer price index	$qdst_c$	Quantity of stock change
ica_{ca}	Quantity of *c* as intermediate input per unit of activity *a*	$\overline{qg}_c$	Base-year quantity of government demand
$icd_{cc'}$	Quantity of commodity *c* as trade input per unit of *c′* produced and sold domestically	$\overline{qinv}_c$	Base-year quantity of private investment demand
$ice_{cc'}$	Quantity of commodity *c* as trade input per exported unit of *c′*	$shif_{if}$	Share of domestic institution *i* in income of factor *f*
$icm_{cc'}$	Quantity of commodity *c* as trade input per imported unit of *c′*	$shii_{ii'}$	Share of net income of *i′* to *i* (*i′* ∈ *INSDNG′*; *i* ∈ *INSDNG*)
$inta_a$	Quantity of aggregate intermediate input per unit of activity output	ta_a	Tax rate for activity *a*
		$\overline{tins}_i$	Exogenous direct tax rate for domestic institution *i*
iva_a	Quantity of value added per unit of activity output	$tins01_i$	0–1 parameter, with 1 for institutions with potentially flexed direct tax rates
$\overline{mps}_i$	Base savings rate for domestic institution *i*	tm_c	Import tariff rate
$mps01_i$	0–1 parameter, with 1 for institutions with potentially flexed direct tax rates	tq_c	Rate of sales tax
		$trnsfr_{if}$	Transfer from factor *f* to institution *i*
pwe_c	Export price (foreign currency)		

(*continued*)

TABLE 8A.1 Continued

Symbol	Explanation	Symbol	Explanation
Greek symbols			
α_a^a	Efficiency parameter in the constant elasticity of substitution (CES) activity function	δ_{cr}^t	CET function share parameter
α_a^{va}	Efficiency parameter in the CES value-added function	δ_{fa}^{va}	CES value-added function share parameter for factor *f* in activity *a*
α_c^{ac}	Shift parameter for the domestic commodity aggregation function	γ_{ch}^m	Subsistence consumption of marketed commodity *c* for household *h*
α_c^q	Armington function shift parameter	θ_{ac}	Yield of output *c* per unit of activity *a*
α_c^t	Function shift parameter for the constant elasticity of transformation (CET)	ρ_a^a	CES production function exponent
β^a	Capital sectoral mobility factor	ρ_a^{va}	CES value-added function exponent
β_{ch}^m	Marginal share of consumption spending on marketed commodity *c* for household *h*	ρ_c^{ac}	Domestic commodity aggregation function exponent
δ_a^a	CES activity function share parameter	ρ_c^q	Armington function exponent
δ_{ac}^{ac}	Share parameter for the domestic commodity aggregation function	ρ_c^t	CET function exponent
δ_{cr}^q	Armington function share parameter	η_{fat}^a	Sector share of new capital
υ_f	Capital depreciation rate	QF_{fa}	Quantity demanded of factor *f*
Exogenous variables			
$\overline{CPI}$	Consumer price index	$\overline{MPSADJ}$	Savings rate scaling factor (= 0 for base)
$\overline{DTINS}$	Change in domestic institution tax share (= 0 for base; exogenous variable)	$\overline{QFS}_f$	Quantity of factor supplied
$\overline{FSAV}$	Foreign savings (foreign currency unit, or FCU)	$\overline{TINSADJ}$	Direct tax scaling factor (= 0 for base; exogenous variable)
$\overline{GADJ}$	Government consumption adjustment	$\overline{WFDIST}_{fa}$	Wage distortion factor for factor *f* in activity *a*
$\overline{IADJ}$	Investment adjustment factor		

Endogenous variables

AWF_{ft}^{a}	Average capital rental rate in time period t
$DMPS$	Change in domestic institution savings rates (= 0 for base; exogenous variable)
DPI	Producer price index for domestically marketed output
EG	Government expenditures
EH_h	Consumption spending for household
EXR	Exchange rate (local currency unit per FCU)
$GSAV$	Government savings
MPS_i	Marginal propensity to save for domestic nongovernment institution (exogenous variable)
PA_a	Activity price (unit gross revenue)
PDD_c	Demand price for commodity produced and sold domestically
PDS_c	Supply price for commodity produced and sold domestically
PE_{cr}	Export price (domestic currency)
$PINTA_a$	Aggregate intermediate input price for activity a
PK_{ft}	Unit price of capital in time period t
PM_{cr}	Import price (domestic currency)
PQ_c	Composite commodity price
PVA_a	Value-added price (factor income per unit of activity)
PX_c	Aggregate producer price for commodity c
$PXAC_{ac}$	Producer price of commodity c for activity a
QA_a	Quantity (level) of activity
QD_c	Quantity sold domestically of domestic output
QE_{cr}	Quantity of exports
QG_c	Government consumption demand for commodity c
QH_{ch}	Quantity consumed of commodity c by household h
QHA_{ach}	Quantity of household home consumption of commodity c from activity a for household h
$QINTA_a$	Quantity of aggregate intermediate input
$QINT_{ca}$	Quantity of commodity c as an intermediate input to activity a
$QINV_c$	Quantity of investment demand for commodity c
QM_{cr}	Quantity of imports of commodity c

(*continued*)

TABLE 8A.1 Continued

Symbol	Explanation	Symbol	Explanation
QQ_c	Quantity of goods supplied to domestic market (composite supply)	$TINS_i$	Direct tax rate for institution i ($i \in INSDNG$)
QT_c	Quantity of commodity demanded as trade input	$TRII_{ii'}$	Transfers from institution i' to i (both in the set $INSDNG$)
QVA_a	Quantity of (aggregate) value-added	WF_f	Average price of factor
QX_c	Aggregated quantity of domestic output of commodity	YF_f	Income of factor f
$QXAC_{ac}$	Quantity of output of commodity c from activity a	YG	Government revenue
RWF_f	Real average factor price	YI_i	Income of domestic nongovernment institution
$TABS$	Total nominal absorption	YIF_{if}	Income to domestic institution i from factor f
		ΔK^a_{fat}	Quantity of new capital by activity a for time period t

SOURCE: Authors, based on the structure of the Dynamic Regional Economywide Model of Ethiopia (DREME).

TABLE 8A.2 Computable general equilibrium model equations

Production and price equations

$$QINT_{ca} = ica_{ca} \cdot QINTA_a \tag{1}$$

$$PINTA_a = \sum_{c \in C} PQ_c \cdot ica_{ca} \tag{2}$$

$$QVA_a = \alpha_a^{va} \cdot \left(\sum_{f \in F} \delta_{fa}^{va} \cdot \left(\alpha_{fa}^{vaf} \cdot QF_{fa} \right)^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}} \tag{3}$$

$$W_f \cdot \overline{WFDIST}_{fa} = PVA_a \cdot QVA_a \cdot \left(\sum_{f \in F'} \delta_{fa}^{va} \cdot \left(\alpha_{fa}^{vaf} \cdot QF_{fa} \right)^{-\rho_a^{va}} \right)^{-1} \cdot \delta_{fa}^{va} \cdot \left(\alpha_{fa}^{vaf} \cdot QF_{fa} \right)^{-\rho_a^{va}-1} \tag{4}$$

$$QF_{fa} = \alpha_{fa}^{van} \cdot \left(\sum_{f' \in F} \delta_{ff'a}^{van} \cdot QF_{f'a}{}^{-\rho_{fa}^{van}} \right)^{-\frac{1}{\rho_{fa}^{van}}} \tag{5}$$

$$W_{f'} \cdot WFDIST_{f'a} = W_f \cdot WFDIST_{fa} \cdot QF_{fa} \cdot \left(\sum_{f'' \in F} \delta_{ff''a}^{van} \cdot QF_{f''a}{}^{-\rho_{fa}^{van}} \right)^{-1} \cdot \delta_{ff'a}^{van} \cdot QF_{f'a}{}^{-\rho_{fa}^{van}-1} \tag{6}$$

$$QVA_a = iva_a \cdot QA_a \tag{7}$$

$$QINTA_a = inta_a \cdot QA_a \tag{8}$$

$$PA_a \cdot (1 - ta_a) \cdot QA_a = PVA_a \cdot QVA_a + PINTA_a \cdot QINTA_a \tag{9}$$

$$QXAC_{ac} = \theta_{ac} \cdot QA_a \tag{10}$$

$$PA_a = \sum_{c \in C} PXAC_{ac} \cdot \theta_{ac} \tag{11}$$

$$QX_c = \alpha_c^{ac} \cdot \left(\sum_{a \in A} \delta_{ac}^{ac} \cdot QXAC_{ac}{}^{-\rho_c^{ac}} \right)^{-\frac{1}{\rho_c^{ac}-1}} \tag{12}$$

$$PXAC_{ac} = PX_c \cdot QX_c \left(\sum_{a \in A'} \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}} \right)^{-1} \cdot \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}-1} \tag{13}$$

$$PE_{cr} = pwe_{cr} \cdot EXR - \sum_{c' \in CT} PQ_c \cdot ice_{c'c} \tag{14}$$

$$QX_c = \alpha_c^t \cdot \left(\sum_r \delta_{cr}^t \cdot QE_{cr}^{\rho_c^t} + \left(1 - \sum_r \delta_{cr}^t\right) \cdot QD_c^{\rho_c^t} \right)^{\frac{1}{\rho_c^t}} \tag{15}$$

(*continued*)

TABLE 8A.2 Continued

$$\frac{QE_{cr}}{QD_c} = \left(\frac{PE_{cr}}{PDS_c} \cdot \frac{1 - \sum_r \delta_{cr}^t}{\delta_c^t} \right)^{\frac{1}{\rho_c^t - 1}} \tag{16}$$

$$QX_c = QD_c + \sum_r QE_{cr} \tag{17}$$

$$PX_c \cdot QX_c = PDS_c \cdot QD_c + \sum_r PE_{cr} \cdot QE_{cr} \tag{18}$$

$$PDD_c = PDS_c + \sum_{c' \in CT} PQ_{c'} \cdot icd_{c'c} \tag{19}$$

$$PM_{cr} = pwm_{cr} \cdot (1 + tm_{cr}) \cdot EXR + \sum_{c' \in CT} PQ_{c'} \cdot icm_{c'c} \tag{20}$$

$$QQ_c = \alpha_c^q \cdot \left(\sum_r \delta_{cr}^q \cdot QM_{cr}^{-\rho_c^q} + (1 - \sum_r \delta_{cr}^q) \cdot QD_c^{-\rho_c^q} \right)^{-\frac{1}{\rho_c^q}} \tag{21}$$

$$\frac{QM_{cr}}{QD_c} = \left(\frac{PDD_c}{PM_c} \cdot \frac{\delta_c^q}{1 - \sum_r \delta_{cr}^q} \right)^{\frac{1}{1 + \rho_c^q}} \tag{22}$$

$$QQ_c = QD_c + \sum_r QM_{cr} \tag{23}$$

$$PQ_c \cdot (1 - tq_c) \cdot QQ_c = PDD_c \cdot QD_c + \sum_r PM_{cr} \cdot QM_{cr} \tag{24}$$

$$QT_c = \sum_{c' \in C'} (icm_{cc'} \cdot QM_{c'} + ice_{cc'} \cdot QE_{c'} + icd_{cc'} \cdot QD_{c'}) \tag{25}$$

$$\overline{CPI} = \sum_{c \in C} PQ_c \cdot cwts_c \tag{26}$$

$$DPI = \sum_{c \in C} PDS_c \cdot dwts_c \tag{27}$$

Institutional incomes and domestic demand equations

$$YF_f = \sum_{a \in A} WF_f \cdot \overline{WFDIST}_{fa} \cdot QF_{fa} \tag{28}$$

TABLE 8A.2 Continued

$$YIF_{if} = shif_{if} \cdot [YF_f - trnsfr_{row\,f} \cdot EXR] \tag{29}$$

$$YI_i = \sum_{f \in F} YIF_{if} + \sum_{i' \in INSDNG'} TRII_{ii'} + trnsfr_{i\,gov} \cdot \overline{CPI} + trnsfr_{i\,row} \cdot EXR \tag{30}$$

$$TRII_{ii'} = shii_{ii'} \cdot (1 - MPS_{i'}) \cdot (1 - \overline{tins}_{i'}) \cdot YI_{i'} \tag{31}$$

$$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{ih}\right) \cdot (1 - MPS_h) \cdot (1 - \overline{tins}_h) \cdot YI_h \tag{32}$$

$$PQ_c \cdot QH_{ch} = PQ_c \cdot \gamma^m_{ch} + \beta^m_{ch} \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma^m_{c'h}\right) \tag{33}$$

$$QINV_c = IADJ \cdot \overline{qinv}_c \tag{34}$$

$$QG_c = \overline{GADJ} \cdot \overline{qg}_c \tag{35}$$

$$EG = \sum_{c \in C} PQ_c \cdot QG_c + \sum_{i \in INSDNG} trnsfr_{i\,gov} \cdot \overline{CPI} \tag{36}$$

System constraints and macroeconomic closures

$$YG = \sum_{i \in INSDNG} \overline{tins}_i \cdot YI_i + \sum_{c \in CMNR} tm_c \cdot pwm_c \cdot QM_c \cdot EXR + \sum_{c \in C} tq_c \cdot PQ_c \cdot QQ_c + \sum_{f \in F} YF_{gov\,f} + trnsfr_{gov\,row} \cdot EXR \tag{37}$$

$$QQ_c = \sum_{a \in A} QINT_{ca} + \sum_{h \in H} QH_{ch} + QG_c + QINV_c + qdst_c + QT_c \tag{38}$$

$$\sum_{a \in A} QF_{fa} = QFS_f \tag{39}$$

$$YG = EG + GSAV \tag{40}$$

$$\sum_{rc \in CMNR} pwm_{cr} \cdot QM_{cr} + \sum_{f \in F} trnsfr_{row\,f} = \sum_{rc \in CENR} pwe_{cr} \cdot QE_{cr} + \sum_{i \in INSD} trnsfr_{i\,row} + FSAV \tag{41}$$

$$\sum_{i \in INSDNG} MPS_i \cdot (1 - \overline{tins}_i) \cdot YI_i + GSAV + EXR \cdot FSAV = \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c \tag{42}$$

$$MPS_i = \overline{mps}_i \cdot (1 + MPSADJ) \tag{43}$$

(*continued*)

TABLE 8A.2 Continued

Capital accumulation and allocation equations

$$AWF_{ft}^{a} = \sum_{a}\left[\left(\frac{QF_{fat}}{\sum_{a'} QF_{fa't}}\right)\cdot WF_{ft}\cdot WFDIST_{fat}\right] \tag{44}$$

$$\eta_{fat}^{a} = \left(\frac{QF_{fat}}{\sum_{a'} QF_{fa't}}\right)\cdot\left(\beta^{a}\cdot\left(\frac{WF_{f,t}\cdot WFDIST_{fat}}{AWF_{ft}^{a}} - 1\right) + 1\right) \tag{45}$$

$$\Delta K_{fat}^{a} = \eta_{fat}^{a}\cdot\left(\frac{\sum_{c} PQ_{ct}\cdot QINV_{ct}}{PK_{ft}}\right) \tag{46}$$

$$PK_{ft} = \sum_{c} PQ_{ct}\cdot\frac{QINV_{ct}}{\sum_{c'} QINV_{c't}} \tag{47}$$

$$QF_{fat+1} = QF_{fat}\cdot\left(1 + \frac{\Delta K_{fat}^{a}}{QF_{fat}} - \upsilon_{f}\right) \tag{48}$$

$$QFS_{ft+1} = QFS_{ft}\cdot\left(1 + \frac{\sum_{a}\Delta K_{fat}}{QFS_{ft}} - \upsilon_{f}\right) \tag{49}$$

SOURCE: Authors, based on the structure of the Dynamic Regional Economywide Model of Ethiopia (DREME).

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