The Role of Agriculture in Development

Implications for Sub-Saharan Africa

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Foreword

Thinking on development has long held that agricultural growth is an important step toward economic development and transformation. However, the new challenges facing African agriculture in today's more globalized environment have led some to question whether conventional wisdom about the role of agriculture in development is still applicable to Africa. There is a shift in emphasis toward nonagricultural growth opportunities, which has the potential to reshape the development strategies of many African countries over the coming decades.

This research report critically examines conventional wisdom and contemporary skepticism. It also develops a country typology reflecting the diversity of conditions across the subcontinent and then examines the role of agriculture in five African countries. The findings indicate that, in many African countries, only agriculture has sufficient scale to increase economic growth significantly over the foreseeable future. Agricultural growth is also more effective at reducing poverty, even in countries that may have the potential for industrial growth driven by rich natural resources. Within the agricultural sector, there are few countries that can generate broad-based growth without expanding the food-staple and livestock subsectors. Based on these findings, the report concludes that although African agriculture faces many new challenges, agriculture and its food subsector cannot be bypassed if Africa is to experience broad-based economic growth and poverty reduction.

Agricultural growth in Africa needs significant increases in public and private investments, and the costs of generating growth can differ significantly across agriculture's subsectors. The report is silent about such costs, which inevitably play an important role in informing development strategies. Nevertheless, the findings of this report will contribute to strategic thinking in many African countries.

Joachim von Braun
Director General, IFPRI

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Summary

This report provides a nuanced perspective on debates about the potential for Africa's smallholder agriculture to stimulate growth and alleviate poverty in an increasingly integrated world. In particular, the report synthesizes both the traditional theoretical and empirical literature on the role of agriculture in the development process and discusses more recent literature that reflects skepticism about the development potential of agriculture for Africa. To examine in greater detail the relevance for Africa of both the "old" and "new" literatures on agriculture, the report provides a typology of African countries based on their stage of development, agricultural conditions, natural resources, and geographic location. This typology highlights that the growth and poverty-reduction potential of agriculture varies substantially across the continent. Moreover, the typology provides the framework for in-depth analysis of agriculture and growth–poverty linkages in five countries (Ethiopia, Ghana, Rwanda, Uganda, and Zambia) via economywide, macro–micro linkage models.

The report shows that despite recent skepticism, agricultural growth is still important for most low-income African countries. The empirical analysis in the various country case studies finds that the pro-growth and pro-poor performance of agriculture will continue to depend on the broad participation of smallholder farmers, and that food staple growth generates more poverty reduction than other agricultural subsectors do. In an increasingly globalized world, however, African farmers face new and different challenges than those encountered by Asian and Latin American countries during their successful transformations. The ability of African farmers to find pathways out of poverty and to contribute actively to the growth process depends on improving infrastructure and education, distributing key technologies and inputs, and promoting producer and marketing organizations that link small farmers to new market chains. African farmers cannot overcome these constraints on their own, and there is a need in the short term for greater public sector involvement in many African countries than is currently fashionable. The challenge is therefore to develop new institutional arrangements between the public and private sectors that foster private sector development without leaving smallholder farmers isolated during the transition.

CHAPTER 1

Introduction

The majority of Sub-Saharan Africa's population lives in rural areas, where poverty and deprivation are most severe. Since almost all rural households depend directly or indirectly on agriculture, and given the large contribution of the sector to the overall economy, one might expect agriculture to be a key component of growth and development. However, whereas agriculture-led growth played an important role in slashing poverty and transforming the economies of many Asian and Latin American countries, the same has not occurred in Africa.[1] Most African countries have not yet met the criteria for a successful agricultural revolution, and factor productivity in African agriculture lags far behind the rest of the world. This failure has led to growing skepticism in the international development community about the relevance of agriculture to growth and poverty reduction. In this report we review and empirically examine this debate and find that the "agro-pessimism" not only is unwarranted but may also undermine attempts to accelerate growth and poverty reduction. Although parts of Africa are indeed disadvantaged by unfavorable natural and geographic conditions, the poor performance of agriculture has often been due to underinvestment in physical, institutional, and human capital.

This report examines whether the conventional wisdom on agriculture's role in the development process is applicable to the contemporary circumstances faced by most African countries. In particular, in Chapter 2 we analyze how the perceived role of agriculture in development has evolved over the past half century. We provide theoretical and empirical evidence to suggest that agricultural growth has powerful leverage effects on the rest of the economy, especially in the early stages of economic transformation, when it accounts for large shares of national income, employment, and exports. Through its linkages to the rest of the economy, agriculture can generate patterns of development that are employment intensive and favorable for the poor. However, although agriculture is generally an important component for Africa's development, its ability to generate growth and reduce poverty varies across and within countries, as well as across different agricultural subsectors. Accordingly, in Chapter 3 we present a typology of African countries classified according to the potential for agriculture to contribute to growth, supplemented with in-depth case studies that examine agriculture, growth, and poverty dynamics in Ethiopia, Ghana, Rwanda, Uganda, and Zambia. Despite having different initial conditions, the case studies found that broad-based agricultural growth, particularly in conjunction with growth in the nonagricultural sector, can contribute significantly to growth and poverty reduction. Furthermore, within agriculture it is growth in the food staples subsector that generates the greatest reduction in poverty, particularly within countries' poorest subregions. Although

[1] "Africa" refers to "Sub-Saharan Africa," which is the regional focus of this report.

important achievements have occurred in these countries, generating further agricultural growth to transform their economies will require meeting a number of conditions, such as increased investments in technology, infrastructure, markets, and health, as well as improved governance. Chapter 4 concludes the report by outlining these and other policy implications.

CHAPTER 2

Agriculture and Development: Conventional Wisdom and Current Debate

Agriculture's Role in Early Development Thinking

Since agriculture constitutes a large share of national output and employs a majority of the labor force in most developing countries, the sector has been integral to any thinking about development.[2] However, the perceived role of agriculture in growth and development has changed considerably over the past half-century. Early classical theory viewed economic development as a growth process requiring the systematic reallocation of factors of production from a primary sector characterized by low productivity, traditional technology, and decreasing returns to a modern industrial sector with higher productivity and increasing returns (Adelman 2001). Agriculture was seen as a low-productivity, traditional sector that only passively contributed to development by providing food and employment. Furthermore, the importance of agriculture was expected to decline as development advanced. Nevertheless, agricultural growth was still considered necessary for development and for a country's transformation from a traditional to a modern economy.

Two key characteristics of agriculture during the early stages of development justified its place in early development thinking. First, agriculture produces goods that directly satisfy basic human needs. Second, agricultural production combines human effort with natural resources, such as land and agroecological assets. Early development theorists believed that, since natural resources were assumed to be freely available, agriculture could grow independently of other economic activities. However, in reality, the dependence of agriculture on a fixed supply of land meant that its expansion was constrained, implying that agricultural output cannot proportionally increase with increased labor supply under a given technology (that is, agriculture suffers from diminishing returns). On the demand side, the need to satisfy basic needs implied that, at the very least, agricultural growth must match population growth to avoid the "Malthusian trap" and stagnant development.

Classical theorists observed that most developing countries comprise "dual' economies. In this view, labor productivity is lower in agriculture than in industry, and hence development requires the movement of agricultural labor into nonagricultural sectors. While it was assumed that nonagricultural innovation and technological change occurred independently of the agricultural sector, both labor and savings had to be released from agriculture to satisfy labor demand and finance capital investment in industry. This assumption explains "why

[2]Agriculture accounts for more than 30 percent of GDP and 60 percent of total employment in Sub-Saharan Africa, excluding South Africa (World Bank 2003a).

Box 2.1 Food Availability Can Become a Constraint on Economic Growth

Latin American countries experienced rapid industrialization between the 1950s and 1970s. Agricultural growth barely matched rising food demand caused by high population growth and urbanization. Industrial growth rose to 8 percent per year during 1965–73, while per capita agricultural production stagnated and even fell in five countries. As a result, food imports increased from an annual growth rate of 3.1 percent during the 1950s to more than 12 percent in the early 1970s. With a rise in world prices for grains, food imports led to substantial strains on the balance of trade and the exchange rate and led to inflationary pressures (de Janvry 1981).

industrial and agrarian revolutions always go together and why economies in which agriculture is stagnant do not show industrial development" (Lewis 1954).[3] Furthermore, the failure of demand for agricultural goods to keep pace with per capita income growth (that is, Engel's law) implies that agricultural surpluses can be generated as long as agricultural productivity growth exceeds the population growth rate. The observation of classical theorists that agricultural surpluses are needed to finance the capital necessary for industrial development still remains important today, because, in spite of the recent liberalization of capital markets, investment in most countries still depends primarily on domestic savings (Ventura 1997).

Beyond the role of agriculture in providing a "reserve army" of labor and capital to industries, classical economists also emphasized the importance of food supplies in sustaining economic growth. If traditional agriculture remained stagnant, then increased employment in the nonagricultural sector would lead to food shortages. Food price increases would raise the cost of living, especially for low-income households with high food consumption shares (that is, large Engel coefficients).[4] The resulting pressure to raise wages would then hamper industrial growth, especially during the early stages of development when technologies are typically labor intensive. Increased labor costs would eventually drive the economy into a stationary state without further growth (see Box 2.1). This is the famous "Ricardian trap" (Ricardo 1817), which formed the foundation for subsequent development theorists (Schultz 1953; Lewis 1954; Fei and Ranis 1961, 1964; Jorgenson 1961). According to Hayami (2001: 84), these theorists understood that "successful industrialization cannot be expected without the parallel effort of increasing food production to avoid the danger of being caught in the Ricardian trap."

Although early development economists saw agricultural growth as an essential component and even a precondition for growth in the rest of economy, the process by which this growth was generated remained beyond the concern of most development economists (Ruttan 2002). For this reason, Lewis's theory was employed to support the industrialization strategies adopted by many developing countries between the 1950s and 1970s. The governments of many of these countries tried to accelerate the industrialization process by heavily taxing agriculture both directly and indirectly until the 1980s (Schiff and Valdez 1992). However,

[3]The observation that few countries have managed to develop without agricultural growth has been asserted repeatedly throughout the literature (see Lipton 2004).

[4]Open economies may use imports to overcome a food shortage, but historically this has been limited to entrepôt city-states such as Hong Kong and Singapore.

as discussed later, the "urban bias" generated by these attempts at industrialization revealed that agricultural and nonagricultural growth could not occur independently of each other.

The Active Role of Agriculture in Growth and Development

The view that agriculture plays only a passive role in development was swept aside by the dynamism of the green revolution in Asia during the late 1960s and early 1970s. The transformation of traditional agriculture into a modern sector revealed the potential of agriculture as a growth sector (see Box 2.2). Simultaneously, it highlighted that science-based technology adapted to a country's ecological conditions is fundamental for agricultural growth. Indeed, advances in mechanical and biological technology helped overcome endowment constraints, particularly in regard to land and labor. Based on this idea, Hayami and Ruttan (1985) espoused an "induced innovation model" that not only emphasized the importance of technical change for agricultural growth but also stressed that technical change is often endogenous to a country's economic system. In other words, successful agricultural innovation is a dynamic process that reflects natural endowments; the degree of demand and supply for agricultural inputs and outputs; and the incentive structure for farmers, scientists, and the public and private sectors. As both the green revolution and the induced innovation model revealed, agricultural productivity growth requires fostering the linkages between the agricultural and nonagricultural sectors. Growth in agriculture therefore does not occur independently of that in nonagricultural sectors, as theorists had originally supposed.

The importance of intersectoral linkages in driving the growth process had already been recognized. Hirschman (1958) was one of the first theorists to emphasize linkage effects in the growth process, although his analysis focused on the backward and forward linkages created by investments in industrial sectors. By contrast, Johnson and Mellor (1961) emphasized the existence of production *and* consumption linkages, both within agriculture as well as between agricultural and nonagricultural sectors. Agricultural production generates forward production linkages when agricultural outputs are supplied as inputs to nonagricultural production. Agricultural growth can therefore contribute to expanding agroprocessing and processed food marketing, which provide new engines of growth and opportunities to substitute for imports. Agriculture also creates backward production linkages through its demand for intermediate inputs such as fertilizers and marketing services. Both of these production linkages are likely to deepen

Box 2.2 Agriculture Accounts for More than Half of GDP Growth between 1960 and 1990

Work by Gollin, Parente, and Rogerson (2002) shows the importance of agriculture during the early stages of development. Using both cross-sectional and panel data for 62 developing countries for the period 1960 to 1990, the authors found that growth in agricultural productivity is quantitatively important in explaining growth in GDP per worker. This direct contribution accounts for 54 percent of GDP growth. Further, countries experiencing increases in agricultural productivity are able to release labor from agriculture into other sectors of the economy. This sectoral shift accounts for a further 29 percent of GDP growth. The remaining 17 percent is derived from nonagricultural growth.

Box 2.3 Agricultural Linkages Change with Different Stages of Development

Using social accounting matrixes for 27 countries, Vogel (1994) examined the strength of the linkages between agriculture and the rest of the economy at different development stages. He found that the backward linkages are typically strong at early stages, while the forward linkages are much weaker. Demand created by rising rural incomes represented almost 70 percent of the backward linkages. Forward linkages strengthen at later stages of development owing to a greater and more complex integration of agricultural production with other sectors.

as an economy modernizes, but decline in relative importance alongside agriculture's share of production (Haggblade, Hazell, and Brown 1989).

The consumption linkages generated by increased rural incomes is the strongest linkage of agriculture in the development process (Thirtle, Piesse, and Lin 2003; also see Box 2.3). Rural households, especially during the early stages of development, provide an important market for domestically produced manufactures and services (Hazell and Roell 1983). Without this market, there are unlikely to be sufficient export opportunities to allow fledgling domestic industries to achieve competitive efficiency in foreign markets through economies of scale.

Surplus agricultural income provides savings for investment in both urban and rural areas (Hart 1998). This savings linkage also works through forward linkages to urban areas. Lower food prices, stimulated by technological change in agriculture, maintain low real wages in industrial sectors and thus foster investment and structural transformation.

In an open economy, sectoral linkages are influenced by foreign trade. The magnitude of the linkage effects depends on the existence of nontradable sectors and on imperfect substitutability between domestic and foreign goods. For example, Fei and Ranis's (1961) assertion that agricultural growth is a prerequisite for urban growth may be less binding if it is possible to substitute imports for domestic agriculture. Nonetheless, even under open economy conditions, agricultural growth typically has stronger links to the rest of the economy than nonagricultural growth (especially in industry) because (1) agricultural output is sold predominantly in domestic markets; (2) intermediate inputs used in agricultural production are less import intensive than in industrial production; and (3) rural demand is usually met by domestically produced goods. Conversely, urban consumption patterns tend to favor imported goods that not only weaken industrial backward linkages but also lead to foreign exchange constraints that hamper capital-intensive industrialization. Export-oriented agriculture can also undermine forward linkages and agricultural production can be constrained by the lack of growth in nonagricultural incomes in both urban and rural areas. Therefore, foreign trade does dampen the linkage effects of agriculture, especially in smaller and more open economies, but the effect is invariably smaller for agriculture than for industry.

The role of agriculture in rural, as opposed to national, development was the focus for many agricultural economists during the 1980s and 1990s (Hazell and Roell 1983; Hazell and Haggblade 1991; Haggblade, Hammer, and Hazell 1991). This shift in emphasis was motivated by (1) imperfect or missing commodity and factor markets; (2) rigidities in rural–urban factor mobility; (3) high transport costs; (4) the existence of rural nontradable sectors; and (5) rural unemployment and underemployment. It was suggested that agricultural productivity growth stimulates rural economies through

Table 2.1 Comparison between family farms and commercial agriculture

Characteristics	Family farms	Commercial agriculture
Role of household labor	Major	Little or none
Community linkages	Strong—based on solidarity and mutual help between household and broader group	Weak—often based on social connection between entrepreneur and local community
Priority objectives	Consume Stock Sell	Sell Buy Consume
Diversification	High, to reduce exposure to risk	Low, specialization in very few crops and activities
Flexibility	High	Low
Size of holding	Small, average 5–10 ha	Large, may exceed 100 ha
Links to market	Weak but becoming stronger	Strong
Land access	Inheritance and social arrangements	Purchase

Source: Toulmin and Gueye (2005).

production and consumption linkages at the *regional* level. Labor demand between agriculture and rural nonfarm activities can create further rural linkage effects, and reciprocal reverse flows from rural nonfarm activities can help finance the purchase of agricultural inputs, which further improves productivity (Reardon et al. 1994; Barrett et al. 2003). Virtually all these studies emphasized the importance of infrastructure in improving the responsiveness of the nonfarm economy to increases in demand from agriculture (Barnes and Binswanger 1986; Ahmed 1987; Evans 1990; Hazell and Haggblade 1991; Ahmed and Donovan 1992; Fan and Hazell 1998). Finally, some regional studies also considered the formation of social capital, suggesting that increased interactions between farmers, input suppliers, processors, and banks might help generate the confidence and trust needed to initiate nonagricultural business and commercial agriculture (Irz et al. 2001).

The linkage effects emanating from agricultural growth have often been analyzed in countries where small farms dominate agriculture and the rural economy, as is the case in most Asian and African countries. Numerous empirical studies have examined the contribution of smallholder farming to agricultural growth and demonstrated that small farms contain poverty by providing an affordable platform from which poor households can experiment with ways to improve their livelihoods and help prevent premature urban migration and the explosive growth of large cities (Eastwood, Lipton, and Newell 2004; Hazell 2004). By contrast, the trickle-down benefits from large-scale commercial agriculture are usually more limited (IFAD 2001; Lipton 2004; also see Table 2.1). Household surveys have also shown that small- and medium-sized farm households usually have expenditure patterns that favor growth in the local nonfarm economy, including rural towns. They spend higher shares of incremental income on rural nontraded goods than do large-scale farmers, thereby generating greater demand for locally produced labor-intensive goods and services (Mellor 1976; Hazell and Roell 1983). Crucially, small farms also contribute to food security in rural areas where high transport and marketing costs can drive up food prices, and at the national level, the higher land productivity of small farms enables poor countries to attain self-sufficiency in staples, such as in cereals, roots and tubers, and livestock.

The strong linkage effects of agriculture suggested to some theorists that agricultural growth could lead broader economic growth during the early stages of industrialization, even in more open countries. Singer (1979) described a "balanced-growth" strategy as one that emphasizes the "national development of agriculture as the primary sector and developing industries with strong emphasis on agriculture–industry linkages and interactions" (Singer 1979). The balanced-growth strategy was later relabeled by Adelman (1984) as an "agricultural-demand-led-industrialization" (ADLI) strategy. This strategy stresses that increasing agricultural productivity expands internal demand for intermediate and consumer goods produced by domestic industries and, in turn, helps support the drive toward industrialization. Such agricultural growth generates incomes for the poorest members of society by increasing the supply of wage goods. By contrast, urban-biased industrialization is seen as characterized by highly dualistic development patterns, deteriorating distributions of income, and slowing growth in both agricultural production and the national economy (Adelman 1984: 938). Adelman also emphasized the distributional impact of agricultural growth. A critical determinant for broad-based participation in the growth process is an equitable ownership of productive assets, especially land, during the earliest stages of development. Thus, the emphasis in agricultural policies should shift "from surplus extraction to surplus creation and to the generation of demand linkages with the rest of economy" (Adelman 1984: 939).

The relationship between agriculture and broader economic growth has recently been examined using dynamic general equilibrium approaches. Theorists from this school develop theoretically consistent general equilibrium models in which individual sectors, including agriculture, interact during the development process. Yang and Zhu (2004) use a two-sector intertemporal model to demonstrate that, without raising agricultural productivity, a traditional economy cannot overcome the fixed supply of natural resources and therefore cannot sustain the growth process. Irrespective of the pace of nonagricultural growth, stagnant agricultural production during the early stages of development prevents structural transformation from a traditional to a modern economy. Irz and Roe (2000) also found that a minimum rate of agricultural productivity growth is necessary to counter population growth and avoid the Malthusian trap. More importantly, the authors found that the demographic and technological characteristics of several Sub-Saharan African countries are consistent with such a poverty trap.

Although the potential for agriculture to serve as an important engine in overall economic growth appears compelling to some theorists, several arguments in the literature suggest that the causality may run in the opposite direction, that is, from nonagricultural to agricultural growth. The main thesis relates to the work initiated by Gardner and Mundlak, who emphasized adjustments in the labor market as the engine of growth in agricultural value added per worker and agricultural incomes. Using data for 1960–2001 from 85 countries, Gardner (2005) found that agricultural growth is surprisingly independent of the per capita income growth for workers in the agricultural sector. Neither is necessary or sufficient for the other. Gardner (2000) also found that, at least for the United States, there is no identifiable connection between any specifically agricultural variable and the growth of U.S. farm-household incomes. Rather, the growth of income in a low-income farm household group appeared to be almost entirely attributable to increased nonfarm earnings as labor markets adjusted to the pre-1960 disequilibrium. The dominant role of labor markets and growth of labor demand in the nonfarm economy in explaining growth in agricultural wages rates was also corroborated by Estudillo and Otsuka (1999), who examined wage rates of agricultural workers in the Philippines. Together these findings support the contemporary skepticism about the role of agriculture in Africa discussed later in this report. However, Tiffin and Irz (2006) used a range of time-series econo-

Box 2.4 Nutrition Is a Key Determinant of Growth

Arcand (2000) shows that the link between nutrition and economic growth is robust to the use of different data sets and different econometric techniques, ranging from OLS to GMM. Using three different cross-country data sets, he found that nutrition affects growth directly, through labor productivity, and indirectly, through improvements in life expectancy. Increasing per capita consumption of dietary energy supply to 2,770 calories per day in countries that are below this would directly increase growth by 0.53 percentage points and indirectly by 0.70 percentage points. Depending on the method and data used, the study found that inadequate nutrition reduces the growth rate of GDP per capita by about 0.20 to 4.7 percentage points. For Sub-Saharan Africa, it accounts for between 0.16 and 4.0 percentage points.

metric methods and concluded that in most cases causality runs from agricultural value added per worker to gross domestic product (GDP) per capita, which supports the argument that agriculture acted as the engine of growth.

Theory has also moved beyond the direct production linkages described in the preceding text. Four of these additional roles are attributed to agriculture during the development process. First, studies have shown a positive link between nutrition and economic growth. Inadequate and irregular access to food increases malnutrition, reduces labor productivity, and is equivalent to a disinvestment in human capital (Bliss and Stern 1978; Strauss 1986; Williamson 1993; Fogel 1994; Wichman 1995). Using an extended Solow growth model, Nadav (1996) examined the importance of nutritional capital. Drawing on a sample of 97 countries, the author found that nutritional levels have a large and significant impact on economic growth (see Box 2.4). This result is consistent with Fogel (1991), who found that increased caloric intake reduced mortality and raised productivity among the working poor during the early stages of Western Europe's development. The author concluded that "bringing the ultra-poor into the labor force and raising the energy available for work by those in the labor force explains about 30 percent of the British growth in per capita incomes over the past two centuries" (Fogel 1991: 63).

Second, agriculture affects economic growth through its potential to stabilize domestic food production and enhance food security. Periodic food crises undermine both political and economic stability, thereby reducing the level and efficiency of investment (Timmer 1989, 1996; Alesina and Perotti 1993; Barro and Sala-i-Martin 1995; Dawe 1996). Although food imports may alleviate such crises temporarily, they are not a viable solution for ensuring long-term food security, especially given the possibility of encountering foreign exchange constraints.

Third, urban bias in public policies has distorted investment incentives and creates strikingly different marginal productivities of capital in urban and rural areas (Fan, Zhang, and Rao 2004). Timmer (2005) suggested that correcting such distortions would shift the overall rate of return to capital and improve the efficiency of resource allocation, thereby increasing factor productivity. Consequently, altering investment toward stimulating agricultural growth also contributes to the generation of broader economic growth.

Finally, the unique decisionmaking processes associated with agriculture, especially smallholder agriculture, can stimulate broader growth by fostering the processes of learning and innovation (Timmer 1988).

Specifically, achieving high yields depends on both hard work and management skills, especially the ability to adopt new technologies. Abramovitz (1986) attributed the ability to adopt productive technologies and operate markets to "social capability" and found that the initial level of social capability explained intercountry differences in the trajectories pursued by different industrializing European countries.[5] Likewise, Temple and Johnson (1996) used the Adelman-Morris index of socioeconomic development as a proxy for social capability. By controlling for income per capita, the authors showed that countries with higher average economic growth rates during 1960–85 had higher levels of social capability in 1960. This area of the literature suggests that to mobilize a country's social capability during the early stages of development, it is necessary to harness farmers' entrepreneurial potential and accordingly develop technologies that improve their management capabilities. These rural entrepreneurs can in turn help drive nonagricultural growth in both rural and urban areas.

Agricultural Growth and Poverty Reduction

Given the size of the agricultural sector in most developing countries, its growth has implications not only for growth in other sectors but also for poverty and inequality. However, as Atkinson (1997) noted, there is no unified theory of income distribution. Rather the empirical debate has revolved around the Kuznets (1955) hypothesis, which predicts that income inequality rises first and then falls with economic development. Kuznets based his speculation on longitudinal data on the industrial countries' development histories. Subsequent cross-country estimations have tended to support this hypothesis. However, recent and more sophisticated country-level analyses find little evidence of a systematic link between inequality and the rate of economic growth (Mellor 1999; Kanbur and Squire 2001). For example, Lopez (2004) accounted for countries' initial conditions in a cross-country estimation and found that growth is more important for poverty reduction during the earliest stages of development (that is, at low income levels). However, the analysis also suggests that inequality increasingly becomes a constraint to poverty reduction during later stages of development.

Most studies show that growth has a significant impact on poverty reduction, but there is substantial variation in the literature about the extent to which poverty declines (Dollar and Kraay 2002). This variation highlights the importance of understanding the structure of growth and its relationship with poverty. Accordingly, linking sectoral growth and poverty reduction has become a focus in the literature (Mellor 1999). A growing econometric literature uses cross-country or time-series data to estimate sectoral and subsectoral growth–poverty elasticities (for example, Timmer 1997; Ravallion and Datt 1999; see also Box 2.5 for more examples). Agricultural growth, as opposed to growth in general, is typically found to be the primary source of poverty reduction. Nonagricultural growth is found to have a greater impact on overall growth, because in many Asian and Latin American countries these sectors have tended to grow faster than agriculture.[6] However, in the early stages of development these high nonagricultural growth rates have typically been achieved only when agriculture is also growing rapidly. The reason is that the resources used for agricultural growth are only marginally

[5]A similar strand of research concerns "tacit knowledge," or learning-by-doing, and its importance for innovation and development (Howells 2002).

[6]The growth decompositions in the appendix show that industrial growth in SSA was in fact below agricultural growth throughout the 1990s.

Box 2.5 Growth in Agriculture Benefits the Poor in Both Rural and Urban Areas

Using panel data from India for 1951 to 1990, Ravallion and Datt (1996) found strong evidence that the urban–rural composition of growth matters to poverty reduction. While urban growth reduced urban poverty, its effect was not significantly different from zero in explaining the rate of poverty reduction nationally. On the other hand, rural growth reduced poverty in rural and urban areas and hence had a significant, positive effect on national poverty reduction.

By disaggregating different types of households in a 1980 Social Accounting Matrix for Indonesia, Thorbecke and Jung (1996) were able to decompose growth linkages into distributional and interdependency effects. The distributional effects are in turn further broken down into intersectional, direct-distributional, and inter-household transfer linkages. They found that the agricultural sector contributes the most to overall poverty alleviation, followed by the services and informal sectors. The manufacturing sector as a whole contributes the least to poverty alleviation, although the food processing and textile subsectors within manufacturing made relatively large contributions to poverty alleviation by employing unskilled workers.

Using data for 1985 to 1996 for China, Fan, Chan-King, and Mukherjee (2005) estimated an econometric model to measure and compare the relative contributions of rural and urban growth to poverty reduction. The authors found that correcting for urban bias leads to higher growth in agriculture, which reduces both rural and urban poverty, though the pro-poor effect is largest for rural areas. On the other hand, urban growth contributes only to urban poverty reduction and its effect on the rural poor is neither positive nor statistically significant.

Based on data from a broad sample of developing countries in the early 1970s and mid-1980s, Bourguignon and Morrison (1998) found that variables that measure agricultural productivity are important in explaining income inequality. Using cross-country regressions for each time period separately and then for the pooled data, the authors found that increasing agricultural productivity is the most efficient path for many countries to reduce poverty and inequality.

competitive with those of other sectors, and thus fast agricultural growth tends to be additive to growth in other sectors and is a stimulant of growth in the labor-intensive nontradable sectors (Mellor 1966, 1976). Therefore, not only does agricultural growth favor the poor, but it also does not undermine the poverty-reducing effects of other sectors (see Box 2.5).

The strong poverty-reducing effect of agricultural growth is due in part to its generation of both agricultural and nonagricultural employment. As mentioned earlier, agriculture is the largest employer in developing countries, either directly or indirectly engaging more than half of the labor force. This dominance is particularly true in labor-abundant economies where small farm households often account for large shares of the rural and poor populations. A key relationship between growth in agriculture and poverty is that agricultural growth directly generates demand for rural labor. Increasing agricultural productivity, especially in countries facing land constraints, requires the intensification of farming systems through yield-enhancing technologies. Although such technologies raise labor productivity, they also require additional labor as well as modern intermediate inputs. Hayami and Ruttan (1985) reviewed the literature on the effect of modern varieties of rice and wheat in Asia and concluded that their introduction typically resulted in an increase in labor requirements per unit of land for each crop, as well as an increase in the number of crops grown (cropping intensity) per year.

Lipton and Longhurst (1989) suggested that, in its initial stages, the green revolution raised the labor intensity of agricultural production, although this higher labor demand was slowly eroded by subsequent adoptions of labor-displacing inputs. Similarly, Binswanger and Quizon (1986) found a low but positive output elasticity of agriculture with respect to labor. Growth in agriculture also results from a shift from low-value to high-value crop or livestock production. Most high-value production, such as in horticulture and intensified livestock production, are highly labor intensive. Moreover, unlike the more capital-intensive industrial sectors, agriculture has demonstrated its ability to generate employment opportunities for the poorest populations.[7] A large body of empirical studies of the green revolution in Asia demonstrates how agricultural growth reached many small farms and raised large numbers of people out of poverty (see Rosegrant and Hazell 2000).

Most of the world's poor are rural and will remain so until 2035 (IFAD 2001). Although agricultural growth is necessary to reduce poverty gaps between urban and rural areas, nonfarm activities are also an important source of cash income for rural households (Ashley and Maxwell 2001). However, the contribution of nonfarm activities to household income is often related to agriculture during the early stages of development. Furthermore, apart from the landless rural population, most rural farm households manage risk by diversifying their incomes through off-farm activities. Agricultural growth reduces poverty by providing a market for nonfarm products, especially given the high labor intensity of nonfarm production. Although the early stages of technological change often directly benefit richer farmers who can more easily adopt the new technology, the consumption linkages generated by rising farm incomes can stimulate growth in local markets. Therefore, even households that do not benefit directly from improved technology will benefit indirectly through improved employment opportunities.

Agricultural growth also benefits rural and urban consumers alike by driving down food prices. The poor typically spend a high share of their income on food and therefore benefit from increases in food production that reduce prices. The strength of this effect depends, however, on the degree to which farm production is tradable and the associated price elasticity of demand. For example, Alston et al. (1998a) showed that, following an increase in supply, the price decrease determining the distribution of benefits between producers and consumers depends on the elasticity of demand, which in turn depends primarily on the size of the market supplied (that is, tradability).[8] The importance of food supply in the growth process has already been discussed earlier; its link to poverty reduction should be understood within the broader context of development. By benefiting the poor, agricultural growth facilitates development by smoothing structural transformation and reducing potentially painful adjustment costs as in-

[7]For land-abundant countries, expansion in cultivated area is often associated with increased labor usage, which provides employment opportunities for the poor even though land productivity may not increase. Chapter 3 examines sectoral variations within agriculture in more detail.

[8]When markets are poorly integrated and infrastructure is underdeveloped, increased output is likely to cause substantial falls in output prices, which consequently reduces the benefits to producers, even though gains to consumers may increase. This is discussed in subsequent sections.

equality becomes more binding on growth later in the development process.

Contemporary Skepticism about the Role of Agriculture in Africa

Despite the theories described in the preceding text and the numerous Asian case studies that support them, there is doubt about whether agriculture can successfully generate enough growth in Africa today (see, for example, Collier 2002; Maxwell and Slater 2003; Ellis 2005). In many respects, this doubt harks back to the immediate post-independence industrialization policies of many low-income countries, including countries in Africa. At that time, priority was given to heavily subsidized and protected industries, while agriculture was penalized and plundered through unfavorable macroeconomic, trade, tax, and pricing policies. More recent skepticism among development scholars about the relevance of agriculture to growth is based mainly on the recognition of changed local and global conditions for Africa as a result of globalization. Some of the key positions promoted by this new breed of agricultural skeptics are elaborated below.

Bypassing Agricultural Development via Cheap Food Imports

The trade perspective that dominated much development thinking in the 1970s and 1980s has returned today with a new emphasis on the benefits of globalization. Early development economists acknowledged that trade could expand sufficiently to provide a necessary growth stimulus, but argued that trade alone is insufficient to promote development (Adelman 2001). For example, based on neoclassical trade theory, it is plausible for resource-rich countries in Africa to export abundant nonagricultural natural resources, such as oil and minerals, and import agricultural goods to meet their domestic demand. This strategy might appear to eliminate the need to modernize agricultural sectors. However, although the static efficiency gains in resource allocation explained by trade theory are an important condition for growth and development, improvements in resource allocation by themselves do not generate sustained growth or broader development. Exports of natural resources can become an engine of growth only if the income generated from exports is channeled into productivity growth in non–natural-resource sectors and helps develop the broader economy.

In practice, it is almost impossible for any country to achieve sustainable growth by following trade theory and fully specializing in the exports of natural resource products. The existence of nontradable sectors such as services and other manufacturing sectors that are not inputs into oil and mineral production implies a much more complicated general equilibrium outcome that takes full account of the interlinkages between tradables and nontradables, and exportables and importables. Economic theory predicts a possible "Dutch Disease" outcome in which growth in the oil and mineral export sector leads to an appreciation of the real exchange rate that penalizes other traded goods sectors, including agriculture. Income distribution is often another serious problem in such an economy, because rents are often captured by a small group of the population in the country or benefit an elite interest group through government intervention. Typically labeled as "enclave economies," these export sectors are often capital intensive with little demand for labor and weak links to the domestic economy through production and consumption.

While the recent "bypass" argument is new in the sense that globalization and trade liberalization provide more export opportunities and make food even cheaper on the international market, the difficulties created by earlier attempts to bypass agriculture remain. Collier (2005) argues that natural extractive resources other than agriculture should be the main economic priority for natural-resource-rich African countries to reach middle income status, whereas for the resource-scarce and coastal countries, the success of economic growth lies in their breaking into global markets for labor-intensive manufacturing exports. Unfortunately, however, most African countries possess a small and inefficient industrial base with an unimpressive growth performance. Turning this performance around in an open trade environment is a daunting task. Not only are fledgling industries expected to compete with the world's best in export markets, but in addition trade liberalization is a two-edged sword that also opens domestic markets to imports that can decimate whole swaths of industry before they have a chance to adjust and compete. The approach contrasts sharply with the proven and successful approach of many Asian countries that first nurtured their industries through growth in protected domestic markets and subsidized exports before requiring them to face the full force of international competition.

Second, there is a scaling-up problem. Industry currently employs about 10 to 15 percent of the labor force in Africa, and its employment elasticity remains low compared to that of agriculture. Even if the performance of the industrial sector were to improve dramatically and grew at the rates observed in many of Asia's "tiger" economies during their golden years, it would still take decades before a large enough share of the labor force could be pulled out of agriculture to lead to a serious reduction in poverty.

Third, despite low world food prices, food costs remain high for many Africans because of high transport costs within the continent. Growing food where it is needed is still the least expensive option for many Africans. Moreover, although fixed exchange rates are largely a thing of the past, increasing food imports still places pressure on foreign exchange markets, leading to currency depreciation and higher food costs in local currencies. This in turn raises real wages and dampens industrialization.

It also needs to be reiterated that, as mentioned earlier, the early industrialization policies adopted by most African countries have resulted in serious urban bias in both public and private investments as well as in governments' macroeconomic and trade policies. Many of these policies have been abandoned, but an urban bias still influences public investment and policy priorities in many countries today. If the new bypass argument further influences the investment policies of African governments and international donors, it would create huge challenges for generating agricultural-led growth in Africa.

The "Rethinking Rural Development" School

More recently, Ashley and Maxwell (2001), Ellis and Harris (2004), and others have advocated "rethinking rural development." They argued that rural areas are highly heterogeneous in size, structure, capability of their populations, patterns of economic activity, and degree of integration with national and international economies. In most areas, agriculture is a relatively small productive sector, which will be commercially incorporated into national and international commodity chains. Most rural households already have diverse and geographically dispersed portfolios of income sources. Considering these changes, those who subscribe to the "rethinking rural development" school question whether agriculture can be the engine of rural growth and suggest instead promoting poverty reduction through a rural livelihoods framework. Ellis and Harris (2004) go further to suggest that public investment should be geared toward improving the ease with which migrants can access major cities, where growth is assumed to be taking place. Migration therefore provides an opportunity for the benefits of growth to trickle down to rural households, where agriculture-based incomes remain stagnant.

Several arguments are also used to question the role of agriculture given the changing global environment. First, long-term global declines in agricultural commodity prices have undermined the profitability of agriculture as a business. Second, the policy instruments that supported the green revolution in Asian countries, such as price supports, fertilizer and credit subsidies, and irrigation schemes, are less acceptable models of public sector intervention today. Finally, the pressure on the natural resource base for agriculture is leading to worsening degradation and even declining productivity. In addition, Ashley and Maxwell (2001) noted that the expectation of equitable growth through agriculture depends on the success of small farms. Yet, the rise in supermarkets, the growing importance of quality standards, and poor access to markets increasingly threaten the ability of smallholder farmers to compete with large-scale, commercial farmers.

Although this school is pessimistic about the potential of agriculture, it provides few viable alternatives to the primary growth role of agriculture in the early stages of development or explains how growth will occur in Africa's urban areas, where high unemployment and informal economies often dominate. Instead, it emphasizes migration and rural nonfarm activities and believes diversification options for multi-occupation and multi-location households can become the relevant engine of growth for rural areas in Africa. Indeed, rural income diversification has been a reality in developing countries for decades. In fact, the first large-scale rural household survey in Africa conducted in 1974–75 in Kenya found that smallholders derived at least half of their incomes from sources other than the farming of their own lands (Kenya Central Bureau of Statistics 1977). Reardon et al. (1994) also reported a similar situation from a series of studies in eight West African countries, and a review of 35 African case studies by Barrett and Reardon (2000) revealed that rural households derived a median of 43 percent of their incomes from the nonfarm economy.

Nevertheless, diversification into nonfarm activities is not an unequivocally positive phenomenon. On the one hand, diversification may reflect a successful structural transformation in which rural workers are gradually absorbed into more lucrative nonfarm jobs, such as teaching, milling, or welding. Entry into these formal jobs often requires some capital, qualifications, and/or possibly social contacts (Start 2001; Thirtle et al. 2001). In this case, widespread rural nonfarm growth can go hand in hand with broad-based agricultural growth, as occurred in several East Asian countries. Alternatively, migration to urban areas can be spurred by desperation rather than by rural success, as is the case in many African countries where diversification into the nonfarm economy is driven by growing land scarcity, declining wages, and poor agricultural growth (Start 2001; Haggblade, Hazell, and Reardon 2002). When used as a coping strategy, nonfarm jobs are frequently informal, risky, and provide low returns, especially when barriers to entry are low and competition for employment is high (Collier and Gunning 1999; Thirtle et al. 2001). The segmented nature of the rural nonfarm economy contributes to a replication of existing inequalities as wealthier farmers can better access those opportunities with the highest returns (Start 2001). As such, agricultural production represents an important safety net for poor farmers by offering both food security and the social support of an agrarian-based community (Bryceson 2000).

Thus, if most African farmers have been unable to find pathways out of poverty despite income diversification strategies over the past several decades, then it is unclear why such a strategy should work better today, particularly in countries where the nonagricultural sectors are not thriving either. Even in many Asian countries, farmers were highly diversified before the green revolution (see evidence from India in Ravallion and Datt 1996). As Lipton (2004) argues, "Europe in 1740–1900 and Asia since 1960 show that when urban industrialization offers major prospects for employment (and poverty reduction), it is fairly late in an already successful, agriculture-led development process." Yet, it is important to distinguish drivers from supporters of rural growth (Kydd 2005). Migration driven by a stagnant agricultural and rural environment or due to growth in low-productivity urban sector activity, such as public service employment, is often a dead end, which Lipton characterizes as "the migration of despair." In this case, migration "depresses wage rates, denudes rural areas of innovators, and hence, while it may briefly relieve extreme need, seldom cuts chronic poverty" (Lipton 2004: 7).

Lessening the Role of Small Farms in Future Agricultural Investment Strategies

Agricultural marketing chains are changing dramatically owing to trade liberalization and broader processes of globalization. The small farmer is increasingly being asked to compete in markets that are much more demanding in terms of quality and food safety, more concentrated and integrated, and much more open to international competition. Supermarkets, for example, are playing a much more dominant role in controlling access to retail markets (Reardon et al. 2003), and direct links to exporters are often essential for accessing high-value export markets. As small farms struggle to diversify into higher value products, they must increasingly meet the requirements of these demanding markets, both at home and overseas. Although these changes may offer new opportunities to small farmers who can successfully access and compete in these transformed markets, they are mainly seen as a serious threat to smallholders (Maxwell 2005).

At the same time as markets have become more unforgiving, structural adjustment and privatization programs have left many small farmers without adequate access to key inputs and services, including farm credit. State agencies no longer provide many direct marketing and service functions to small farms, leaving a vacuum that the private sector has yet to fill in many countries (Kherallah et al. 2002). The removal of subsidies has also made some key inputs, such as fertilizer, prohibitively expensive for many small farmers, and the removal of price stabilization programs has exposed farmers to greater price volatility. These problems are especially difficult for small farmers living in more remote regions with poor infrastructure and market access. Within this context, there is a growing view that most smallholders do not have a viable future in farming, and that agricultural development should now focus on larger and commercially oriented farms that can successfully link to the new types of market chains.

Admittedly, many of the economic and social advantages offered by small farms (as discussed earlier) slowly disappear as countries develop and labor becomes scarcer relative to land and capital, leading to a natural transition toward larger farms and an exodus of small farm workers to towns and nonfarm jobs. Yet, this transition does not normally begin until countries have grown out of low-income status, and it typically takes several generations to unfold. A common misdiagnosis stems from overlooking this broader economic context for determining the economics of farm size.

For most low-income countries, the problem is not that small farms are inherently unviable in today's marketplace, but that they face an increasingly tilted playing field that, if left unchecked, could lead to their premature demise. Key requirements for ensuring their survival will be improving infrastructure and education, ensuring that small farms get the technologies and key inputs that they need, and promoting producer marketing organizations that can link small farmers to the new market chains. Small farmers can-

Table 2.2 The size of Sub-Saharan Africa's agricultural markets

	Market value (US$ billion)			
	Eastern Africa	Southern Africa	Western Africa	Total Africa
Traditional exports to non-African countries	2.2	2.4	4.0	8.6
Nontraditional exports to non-African countries	1.3	2.8	2.0	6.1
Other exports to non-African countries	0.5	0.7	0.7	1.9
Intra-African trade	0.4	1.1	0.4	1.9
Domestic markets for food staples	17.6	12.1	20.1	49.7

Sources: Trade figures are from UN COMTRADE (United Nations 2005) and are 1996–2000 averages; domestic-market figures are for 2000 from FAO (2003).

Note: Domestic market demand includes the value of own consumption.

not do all these things on their own, and the public, private, and nongovernmental organization (NGO) sectors all have important roles to play. The social and economic benefits from these kinds of interventions have the potential to be enormous.

Focusing Agricultural Development on High-Value Commodities and Value-Added Processing

With chronic global surpluses of major food staples and rapid expansion in international agricultural trade, many see high-value commodities such as fruits, flowers and vegetables as the best opportunities for developing country farmers. In many successfully transformed countries, domestic demand for these products is growing rapidly and providing ready market outlets for increased domestic production. Yet, in many low-income countries, domestic demand is much weaker, and the best opportunities are seen in export markets. Many African countries, for example, are being encouraged to expand into high-value, nontraditional exports, as well as to improve the quality of their traditional tree crop exports.

In reality, the market opportunities for African agriculture are more nuanced (Diao and Hazell 2004). There are opportunities for improving traditional exports through better quality and niche markets, and nontraditional exports are growing quite fast, albeit from a small base, but the greatest market potential for most African farmers still lies in domestic and regional markets for food staples (cereals, roots and tubers, pulses, oil crops, and livestock products). For Africa as a whole, the consumption of these commodities accounts for more than 70 percent of agricultural output and is projected to double by 2015. This growth will add about US$50 billion per year to demand in 1996–2000 prices (see Table 2.2). Moreover, with increasing commercialization and urbanization, much of this additional demand will translate into market transactions and not just additional on-farm consumption. No other agricultural markets could offer such growth potential and benefit to Africa's small farmers at such huge scales. Many small farms could significantly increase their incomes if they could capture a large share of this market growth.

Roles of the Public and Private Sectors in Africa's Agricultural Development

As agricultural markets become more globalized and consumer driven, it is now fashionable to think that the private sector and producer organizations can perform most market chain functions. In this new paradigm, the government's role should be limited to creating an enabling environment, such as setting and regulating grades and standards, ensuring food safety, and registering and enforcing contracts. This contrasts sharply with the key role that the public sector played in food staple market chains during the early years of the green revolution in Asia, which is characterized as a state-driven, market-mediated, and small-farmer based strategy to increase national self-sufficiency in food grains (Sida 2006).

At that time, Asian governments set out to stimulate food production by providing most key services themselves, including investments in irrigation and transport infrastructure, research and extension services, marketing chains for the supply of improved seeds and fertilizer, and credit provision. The governments often intervened to stabilize prices for producers and consumers alike, and provided subsidies for many key inputs to encourage their uptake. These governments assumed a leading role in agricultural development and went far beyond a facilitating role. Work at IFPRI on India shows the government interventions played a key role in launching the green revolution (Dorward et al. 2004a, Chapter 3). They also helped ensure that small farmers were able to participate, which contributed greatly to the levels of poverty reduction achieved. The authors' calculations show that most of these policies and interventions had favorable benefit/cost ratios in the early years, but the ratios worsened over time once the interventions had served their primary purposes. Unfortunately, once these interventions are institutionalized, they are very difficult to remove, and as input use increased, the costs to the governments soared. Today, for example, India spends about $10 billion per year on unproductive subsidies.

The international development community is concerned about the high costs and inefficiencies of public interventions in Asia. Accordingly, it generally recommends that Africa launch an agricultural revolution relying almost exclusively on the private sector and producer organizations. However, there is little evidence to suggest that the private sector can take the lead in market chains for staple foods during the early stages of agricultural development. As farmers struggle with low productivity and high subsistence needs, low input use, low incomes, poor infrastructure, high risks, and the like, the amount of profit to be made in market chains for food staples remains low and unattractive for much private investment. A growing body of studies also shows that important institutional and market failures are to be expected early in the development process (Dorward, Kydd, and Poulton 1998). For example, no Asian country developed its food staple agriculture from a subsistence to market orientation without public intervention in the market chains.

Current skepticism about African agriculture is thus borne out of the new challenges facing Africa and the world today. However, the theoretical and empirical evidence still suggests an important role for agriculture in Africa's development as well as an active role for the public sector. This is not a recommendation to return to costly and inefficient parastatals or hefty and poorly targeted subsidies. Nor is it an argument against a strong role for the private sector, especially in areas where it does work, such as in many high-value market chains. What is needed is a better understanding of the aspects of public intervention that worked in Asia (for example, Dorward, Kydd, and Poulton 1998). Then, important lessons can be drawn about the institutional innovations needed to bring those essential ingredients to Africa, such as through innovative public–private partnerships. Even most Asian countries still remain cautious about moving too rapidly toward fully privatized markets for food staples.

CHAPTER 3

The Role of Agriculture in Africa: Selected Country Case Studies

The debate summarized in earlier chapters is far from resolved, but greater resolution is possible if it is recognized that country context matters and agriculture has different roles to play in different circumstances. For example, the agricultural sector as a whole, and food staples in particular, would seem to be more important in the early stages of economic development when they dominate a country's national income and employment, but these roles diminish as a country develops and agriculture becomes a relatively small sector. Agriculture also has a bigger role in countries with good agricultural potential and limited prospects for export earnings from minerals or manufacturing. Agriculture is often found to be more important in developing countries dominated by small family farms, while countries with dynamic and growing national economies and rising per capita incomes offer farmers more opportunities to diversify into higher value products and nonfarm sources of income. Conversely, in poorer and slower growing economies, opportunities for income diversification and exit strategies are much more limited. To bring greater contextual specificity to the debate requires construction of a country typology.

A Typology of African Countries

The theoretical and empirical literature suggests that the role of agriculture is closely related to a country's stage of development. Accordingly, per capita income is used in the typology as a proxy for development to classify African countries into low- and middle-income groups (see Table 3.1). Only 8 percent of Africa's population lives in middle-income countries, where average gross domestic product (GDP) per capita is almost ten times higher than the average for low-income Africa (see Table A1 in the appendix).[9] Agriculture is less important in middle-income countries and on average generates less than 10 percent of GDP. Higher average per capita incomes typically correspond to lower poverty rates, with middle-income countries in total containing less than 1 percent of Africa's poor population. However, one-half of the population in middle-income countries still lives in rural areas, and in most cases the poor still depend on agriculture for their livelihoods. For example, two-thirds of Swaziland's population lives on less than a dollar a day, with a vast majority of these people living in rural areas dependent on agricultural incomes. Therefore, agriculture may not be a dominant sector in most middle-income economies, but it is still likely to play an important role in reducing poverty.

[9]These countries are shown in the far-right column of the typology and have per capita GDP above US$1,000 per year.

Table 3.1 Cross-country typology for Sub-Saharan Africa

		Agricultural share above average (34% GDP)		Agricultural share below average (34% GDP)		
		Falling GDP p.c. (1991–2001)	**Rising GDP p.c. (1991–2001)**	**Falling GDP p.c. (1991–2001)**	**Rising GDP p.c. (1991–2001)**	**Middle income countries (> US$1,000 p.c.)**
More-favorable agricultural conditions (top two-thirds of FAO country-level farming system assessment)	Coastal country	The Gambia (38) Togo (63)	Benin (16) Ghana (45) Guinea-Bissau (84) Tanzania (78)	Côte d'Ivoire (14)	Kenya (24) Mozambique (33) Senegal (13)	Mauritius (5) South Africa (2)
	Land-locked country		Burkina Faso (57) Ethiopia (85) Malawi (51) Uganda (41)		Lesotho (41) Zimbabwe (52)	Swaziland (66)
	Mineral-rich country	Cameroon (40) Central African Republic (82) Democratic Republic of Congo (92) Sierra Leone (72)	Sudan (80)	Angola (72) Republic of Congo (52) Zambia (79)	Guinea (64) Nigeria (68)	Equatorial Guinea (32)
Less-favorable agricultural conditions (lowest third of FAO country-level farming system assessment)		Comoros (56) Burundi (65) Niger (75)	Mali (72) Rwanda (59) Chad (82)	Madagascar (46)	Mauritania (27)	Cape Verde (27) Botswana (22) Gabon (23) Namibia (34)

Notes: The numbers in parentheses show the percentage of each nation's population living below the poverty line in 1999. The definition of the poverty line used here is a dollar per day (World Bank 1995, 1997, 2003; UNIDO 2004). Agricultural conditions are based on FAO Farming Systems' potentials weighted by system's land coverage within each country (Dixon et al. 2001). Agriculture shares are for 2001 from World Development Indicators (World Bank 2005). Geographic and natural resource classification based on UNIDO (2004). Per capita GDP growth is measured in constant local currency. Per capita GDP is in U.S. dollars (not international dollars). Six Sub-Saharan countries are excluded owing to data limitations (Eritrea, Liberia, Mayotte, São Tomé and Principe, Seychelles, and Somalia). p.c., per capita.

This study focuses on low-income countries. More than 90 percent of Africa's population lives in low-income countries where per capita incomes average 1 dollar per day. Agriculture accounts for around one-third of GDP, and two-thirds of the population live in rural areas. The industrial sector, including mining, accounts for less than a quarter of GDP. Although services collectively comprise the largest sector on average, this sector consists mainly of public and nontradable services. For example, the government in most low-income African countries accounts for around 10 percent of GDP. Most private services are closely tied to agricultural and industrial production and are therefore unlikely to become engines of growth during the early stages of development.

To understand better the role of agriculture within the low-income group it is necessary to further distinguish countries according to a range of indicators reflecting agricultural potential and alternative sources of growth (see Table 3.1). Agricultural potentials draw on a classificatory scheme developed by Dixon, Gulliver, and Gibbon (2001) and include a range of measures such as agroecological conditions and population densities.[10] According to this indicator, 26 out of the 34 low-income African countries have more favorable agricultural potential. However, even in countries with favorable conditions, agriculture competes with other sectors for limited resources. Countries with rich mineral and oil endowments may have alternative sources of growth and so are separated in the typology. Furthermore, coastal countries may have advantages in export-oriented agriculture or greater opportunities in nonagricultural sectors. Therefore, coastal and landlocked countries are also separated. The typology therefore identifies four groups of low-income countries: (1) coastal; (2) landlocked; (3) mineral-rich; and (4) less favorable agricultural potential. The characteristics of each group are discussed in turn.

Coastal Countries without Large Mineral Resources

More than four-fifths of Africa's population lives in one of the 26 low-income countries classified as having more favorable agricultural conditions. Although 17 of these 26 countries have access to the coast, many have significant mineral or oil resources and so are classified as mineral-rich in the typology. Therefore, although half of Africa's population lives in coastal countries, only one-fifth lives in coastal countries without large mineral or oil resources. These ten countries form the first group in the typology (first row in Table 3.1). These countries have more favorable agricultural conditions, fewer natural barriers to trade, and their development is less likely to be driven by mineral-based industry.

The first group of coastal countries lies mostly in West Africa, with the exception of Kenya, Mozambique, and Tanzania along the eastern coast. They have grown at an annual rate of 3.5 percent over the past 15 years, which is higher than the average for low-income Africa. Agriculture accounts for one-third of GDP compared to one-fifth for industry. Thus, although the 3.5 percent growth rate of agriculture per year is lower than that of industry, the sector's contribution to overall GDP growth is larger.

Almost two-thirds of the population of these coastal countries lives in rural areas, where poverty is most severe. However, poverty as a whole is lower in coastal countries, with 41 percent of the population falling below the dollar-a-day poverty line compared to more than 56 percent for low-income Africa as a whole. Furthermore, a number of outlier countries raise the average poverty rate for the coastal group, such as Guinea-Bissau and Tanzania. The remaining coastal countries have substantially lower poverty rates, many of which fall below the average poverty rate for middle-income African countries.

[10]See Tables A1 and A2 in the appendix for more details on the data underlying the typology.

Landlocked Countries without Large Mineral Resources

One characteristic of Africa is its large number of landlocked countries. The 14 low-income African countries that do not have coastal access account for more than a third of Africa's total population. This is substantially higher than in other developing regions of the world. Being landlocked can present a significant natural barrier to trade and can undermine both agricultural and industrial export opportunities. Furthermore, many of Africa's landlocked countries have particularly poor agricultural conditions, especially those lying in the Sahel. However, the second group of countries in the typology includes only the landlocked countries that have more favorable agricultural conditions and that do not have large mineral or oil resources (second row in Table 3.1). These six countries, which are classified as "landlocked" in the typology, account for one-fifth of Africa's total population.

Similar to the first group of coastal countries, agriculture and industry account for one-third and one-fifth of GDP respectively. Although per capita GDP is lower in landlocked countries than in coastal countries, the former has experienced slightly faster growth over the past 15 years. The composition of growth in landlocked and coastal countries is very similar, with agriculture growing more slowly than industry but contributing more to the overall GDP growth. Despite similar economic structures, the share of the population living in rural areas is substantially higher in landlocked countries at almost 80 percent. Poverty is also higher, with 55 percent of the population falling below the dollar-a-day poverty line. Again, the average level of poverty is biased upward by outlier countries, in this case by Ethiopia's extremely high poverty rate. However, after removing outliers, the remaining landlocked countries still tend to have higher poverty rates than coastal countries. Therefore, despite initial conditions similar to those of coastal countries, landlocked countries tend to have lower per capita incomes, higher poverty, and larger rural populations.

Mineral-Rich Countries

A further characteristic of Africa is its substantial mineral wealth. Two-fifths of Africa's population lives in low-income countries with both favorable agricultural conditions and significant mineral and oil resources. Furthermore, the countries have grown slowly over the past 15 years at an average GDP growth rate of only 1.4 percent per year. As expected, industry, which includes mining, is more important in mineral-rich countries, accounting for 35 percent of GDP. However, as with other low-income African countries, agriculture still generates one-third of GDP in mineral-rich countries. Moreover, agriculture has grown at 2.8 percent per year compared to only 1.3 percent for industry. Therefore, agriculture is still the primary source of growth in many mineral-rich countries, contributing on average twice as much as industry to overall GDP growth.

Average per capita GDP is highest for mineral-rich countries. However, there is considerable variation in this group, which includes countries with both the highest and lowest GDP per capita among all low-income African countries. Although the industrial sector is larger in mineral-rich countries, almost 60 percent of the population still lives in rural areas. Furthermore, despite higher average per capita incomes, poverty is substantially higher in mineral-rich countries, with 70 percent of the population falling below the dollar-a-day poverty line. Therefore, while many low-income African countries are well endowed with mineral resources and therefore have alternative opportunities for growth outside of agriculture, these natural endowments have so far failed to generate significant growth or poverty reduction.

Countries with Less Favorable Agricultural Potential

The final group includes countries with less favorable agricultural conditions, regardless of whether they are landlocked, coastal, or mineral-rich. Only 10 percent of Africa's population lives in these countries. There is considerable diversity across countries in this group. Many are situated in the Sahel and have poor access to the coast. By contrast, the coastal countries in this group are island states, while the landlocked countries include mountainous Rwanda and Burundi. Despite poor conditions, agriculture generates almost 40 percent of GDP, which is twice the size of industry. Furthermore, agriculture has grown substantially faster than industry over the past 15 years. Strong growth and a large share of GDP imply that agriculture has been the primary driver of growth in these countries, contributing almost three times more to GDP growth than has industry.

Almost three-quarters of the population lives in rural areas, which is substantially higher than the average for low-income Africa. Average GDP per capita is particularly low in countries with less favorable agricultural conditions, although there is substantial variation between landlocked and coastal countries within this group. More than 60 percent of the less favored countries' population lives in poverty, with particularly high poverty in mineral-rich countries. Countries with less favorable agricultural conditions therefore face huge challenges and yet lack many of the resources of other African countries. However, despite poor conditions, agriculture has and continues to offer the only opportunity for growth and poverty reduction for many of these countries.

Country Case Studies

The typology reveals the diversity of conditions and challenges facing African countries, thus indicating the difficulty of drawing general conclusions for the continent. Therefore, when considering the role of agriculture in Africa's development, it is particularly important to account for such diversity. The remainder of this chapter examines the role of agriculture under different initial conditions by selecting countries from the four different groups identified in the typology. In each case study country, the potential magnitude of the contribution of agriculture to growth and to poverty reduction is examined and contrasted with alternative sources of growth, using economy-wide models that compare different structures of growth with their poverty outcomes. The selected case study countries include Ghana (coastal), Ethiopia and Uganda (landlocked), Zambia (mineral-rich), and Rwanda (less favorable agricultural conditions).

Overview of the Case Study Countries

Both Ethiopia and Rwanda are landlocked and depend on rainfall for agricultural production. Vulnerability to recurrent droughts has made Ethiopia one of the world's poorest countries. Rwanda is still recovering from genocide, which caused a significant decline in its economy, including agriculture. In both countries, agriculture accounts for a substantial share of GDP, and more than four-fifths of the population lives in rural areas (see Table 3.2). By contrast, manufacturing accounts for a small share of GDP and is dominated by agriculture-related processing. This is particularly true for Ethiopia, where industry generates only 11 percent of GDP, the lowest share in all low-income African countries. Although the service sector is large and has grown rapidly over the past 15 years, much of this growth has been driven by the public sector, especially in the capital cities.

By contrast, Ghana and Uganda have experienced high and stable GDP and agricultural growth over a sustained period. Ghana in particular is one of only a handful of African countries to have consistently maintained a positive per capita GDP annual growth rate over the past 20 years. Ghana is also the only coastal country among the five case studies and has a relatively high share of industry to GDP owing to agroprocessing, textile manufacturing, and gold mining. However, agriculture still generates one-third of GDP. Within agriculture, crops and livestock

Table 3.2 Comparative indicators across the selected case study countries (%)

	Share of GDP (1999)		GDP growth rate (1985–99)		Poverty headcount		
	Agriculture	Industry	Agriculture	Total	$1-a-day	National rate	
Ethiopia	52.3	11.1	2.7	1.8	85.2	51.1 (1992/93)	44.2 (1999/2000)
Ghana	35.9	25.2	2.7	5.0	44.8	51.7 (1991/92)	39.5 (1998/99)
Rwanda	40.5	21.6	3.2	1.8	58.9	40.0 (1983–85)	60.3 (1999/2001)
Uganda	36.4	20.9	3.5	9.0	40.8	56.0 (1991/92)	35.0 (1999/2000)
Zambia	22.1	25.6	4.5	–0.3	79.3	68.9 (1991)	75.4 (1998)

Sources: World Development Indicators (World Bank 2005); UNIDO (2004); MOFED, Ethiopia (2003); GSS, Ghana (2004); MINECOFIN, Rwanda (2002); Okidi et al. (2004); Thurlow and Wobst (2004).

account for three-quarters of agricultural production and are the primary activity of two-fifths of the population (McKay and Aryeetey 2004).

Agriculture contributes less to GDP in Zambia than it does in the other four case study countries. This circumstance reflects the country's long-standing dependence on copper production and exports, which have fostered a dualistic economy biased toward urban-based industrialization. In addition to its vulnerability to volatile international prices, copper production is a capital-intensive, enclave industry with weak backward linkages into rural areas. Therefore, growth driven by the mining sector has yet to provide the magnitude of poverty reduction needed in this impoverished country.

The five countries share not only a high concentration of poverty in rural areas, but also a history of bias against the agricultural sector that only recently has been reversed through policy reforms. For example, of a sample of 18 developing countries, Ghana had the highest level of discrimination against agriculture during the 1960s and 1970s (Krueger 1993: 61–73). Until the early 1980s, self-proclaimed socialist regimes in some of these five countries frequently espoused an attempt to use central planning to restructure the economy away from external dependence. Food prices were kept low for vocal urban interests and to finance import-substitution industrialization. Yet, rather than improving agricultural technology and facilitating the positive linkages of agriculture to the rest of the economy, the use of inefficient marketing boards, overvalued exchange rates, and pan-territorial pricing resulted in decelerating agricultural growth and reductions in farm incomes. Urban-biased policies were not only economically inefficient, but also financially unsustainable, particularly as international commodity prices for their traditional agricultural and mineral exports declined. The heavily subsidized and protected state-managed industries were highly inefficient and uncompetitive in both international and domestic markets, while stagnant agriculture resulted in growing food gaps in domestic markets and declines in agricultural exports. These conditions induced foreign exchange constraints, higher food prices, and low savings, which themselves dampened the industrialization process. Consequently, not only did agriculture suffer but so did other sectors in these economies.

Precipitated by either economic crisis or political change, most of the case study countries adopted structural reforms during the 1980s and 1990s that were based on restoring macroeconomic stability and liberalizing trade and domestic markets. Correcting the adverse agricultural terms-of-trade created under import substitution and reducing or eliminating export taxes on agricultural products have made the agricultural sector one of the main beneficiaries of the reforms. Moreover, the typical devaluation of the exchange rates helped eliminate the black market premium on export sectors. Although dismantling costly and inefficient parastatals provided farmers with improved incentives, the structural adjustment and privatization programs have left many small farmers without adequate access to key inputs and services, including farm credits (see, for example, Sahn, Dorosh, and Younger 1997, for a detailed discussion about the impact of structural adjustment programs on the poor in Africa). The outcome of long-term, urban-biased investments and policies still influences the allocation of public resources and investments, although the role of agriculture in growth and poverty reduction is increasingly being emphasized in these countries.

Nevertheless, the shift toward support for agriculture during the reform and adjustment period, either indirectly through the removal of adverse policies or directly through providing market support for targeted agricultural commodities (such as price supports for cocoa in Ghana), has had a positive impact on agricultural growth and poverty reduction in these countries over the past decade. As seen in Table 3.3, the incidence of poverty has declined in four of the five countries at the national levels, except for Rwanda, where the economy was still recovering from the genocide of 1994. In Zambia, poverty declines in rural regions were accompanied by poverty increases in urban areas owing to the shocks created by the collapse of copper prices and the collapse of state-supported urban industry under the structural adjustment process.

The potential contribution of agriculture to poverty reduction in the five selected countries is analyzed using economywide models developed for each country. The following section describes the major features of the models and how microlevel poverty data are integrated with macrolevel growth data.

Economywide Models and Data Sources

The five country studies use economywide simulation models to examine the contribution of agriculture to growth and poverty reduction. Two different types of models are used: economywide multimarket (EMM) models for Ethiopia, Ghana, and Rwanda, and computable general equilibrium (CGE) models for Uganda and Zambia. Although the CGE approach is preferable, the choice of methodology was constrained by the availability of the data for each country. Only in Uganda and Zambia were sufficient data available to construct the highly disaggregated social accounting matrices necessary to calibrate the CGE models. However, despite their differences, both types of models disaggregate the national economies into subnational provinces or regions so that the analysis of growth–poverty linkages can be conducted at the subnational level. For example, in the remote regions where the rural economy is dominant and poverty levels are high, the growth–poverty linkages may be different than in regions with high levels of urbanization and concentrated industrial production and urban employment. The models are described below, and a more detailed mathematical description is provided in the appendix.

Specification of the EMM Model. The EMM model captures the detailed structure of the agricultural sector. This can be seen in Table A3 in the appendix, where, for example, 34 sectors are identified in the

Table 3.3 Comparison of agricultural and nonagricultural growth scenarios

	Baseline scenario	Agriculture-led scenario	Nonagriculture-led scenario[a]
Ethiopia (2003–15)			
Annual per capita GDP growth rate (%)	0.5	2.4	2.4
Annual GDP growth rate (%)	3.1	5.0	5.0
Agriculture	2.5	5.0	2.7
Nonagriculture	3.7	5.0	7.0
Poverty headcount by 2015 (%)	44.3	26.5	37.3
Difference in poor population in 2015 (1,000)		–15,904	–6,280
Poverty–growth elasticity	NA	–1.66	–0.73
Ghana (2003–15)			
Annual per capita GDP growth rate (%)	2.2	3.1	3.1
Annual GDP growth rate (%)	4.7	5.7	5.7
Agriculture	4.6	7.0	4.6
Nonagriculture	4.8	4.8	6.2
Poverty headcount by 2015 (%)	23.7	17.3	21.5
Difference in poor population in 2015 (1,000)		–1,722	–586
Poverty–growth elasticity	–1.49	–1.78	–1.33
Rwanda (2003–15)			
Annual per capita GDP growth rate (%)	0.7	3.2	3.2
Annual GDP growth rate (%)	3.4	6.0	6.0
Agriculture	3.3	7.9	3.5
Nonagriculture	3.4	3.5	8.1
Poverty headcount by 2015 (%)	55.5	34.6	43.3
Difference in poor population in 2015 (1,000)		–2,280	–1,334
Poverty–growth elasticity	–1.09	–1.41	–0.84
Uganda (1999–2015)			
Annual per capita GDP growth rate (%)	1.6	2.8	2.8
Annual GDP growth rate (%)	5.2	6.4	6.4
Agriculture	5.1	7.6	5.3
Nonagriculture	5.3	5.2	7.4
Poverty headcount by 2015 (%)	27.8	17.6	21.7
Difference in poor population in 2015 (1,000)		–3,993	–2,388
Poverty–growth elasticity	–0.98	–1.58	–1.10
Zambia (2001–15)			
Annual per capita GDP growth rate (%)	2.0	3.0	3.0
Annual GDP growth rate (%)	4.0	5.0	5.0
Agriculture	4.6	7.7	4.5
Nonagriculture	3.8	4.0	5.1
Poverty headcount by 2015 (%)	68.3	58.9	64.4
Difference in poor population in 2015 (1,000)		–1,253	–529
Poverty–growth elasticity	–0.35	–0.58	–0.38

Source: Authors' simulations and calculations.
[a]The nonagricultural simulation for Zambia involved accelerating growth in the industrial sectors only.

Ethiopian model, 32 of which are in agriculture. By contrast, the disaggregation of the CGE models is more evenly balanced across agricultural and nonagricultural sectors. For example, of the 27 sectors in the Zambian model, 13 are agricultural, 9 are industrial, and 5 are service sectors. Although the CGE models are better at capturing cross-sector growth linkages during the production process, they contain less detailed information on agriculture, such as the production technologies used in the many agricultural subsectors. These differences may not prove too severe, however, because consumption linkages outweigh production linkages in most developing countries during their early stages of development (Vogel 1994). The ability to capture detailed consumption linkages depends largely on the disaggregation of households' income and expenditure patterns. In this regard, all of the models have highly disaggregated representative households and are linked directly to household expenditure surveys to ensure that the most detailed household information is retained. The models are disaggregated further across regions within each country to capture the geographic heterogeneity of sectors and households. For example, 56 zones are included in the Ethiopian EMM model. In this regard, the EMM models are considerably more disaggregated than the CGE models.

The EMM model is based on neoclassical microeconomic theory. In the model, there are aggregate producers representing subnational production in each sector and for rural and urban areas. The supply functions are derived under producer profit maximization based on the producer prices of all commodities. In the agricultural sector, these supply functions have two subcomponents: (1) yield functions and (2) land allocation functions responsive to changing profitability across different crops given the total available land. Where data are available, the supply functions are disaggregated further across technologies. In the case of the Ethiopian EMM model, there are as many as 15 different technologies for producing similar crops or livestock products within specific subnational regions. For example, the yield functions for farmers employing modern inputs, such as fertilizer or improved seeds, have higher productivity coefficients than those not using modern inputs. The area functions for each crop are also disaggregated according to the use of modern inputs. For example, the area functions for maize production include farmers using fertilizer only, those using fertilizer and improved seeds, or those not using any modern inputs. Further, since irrigation is treated as one of these modern inputs, there are different supply functions for irrigated and rainfed crop production.

Representative consumers are aggregated from household survey data to represent an average household's consumption patterns in rural and urban areas of each subnational region. The demand functions are derived from utility maximization based on prices and income. Income is generated from both agricultural and nonagricultural activities and is an endogenous variable that links supply with demand as in a typical general equilibrium model.

As the name of the model suggests, a multiple market structure is specified. There is perfect substitution between domestically and internationally produced commodities. However, transportation and other market costs distinguish trade in the domestic market from imports and exports. For example, although imported maize is assumed to be perfectly substitutable with domestically produced maize in consumers' demand functions, maize may still not be profitable to import if its domestic price is lower than the import parity price less any transactions costs. Maize imports can occur only when domestic demand for maize grows faster than domestic supply and the local market price rises significantly. A similar situation applies to exported commodities. Even though certain horticultural products are exportable, if domestic production is not competitive in international markets, owing to either low productivity or high transactions costs, then exports will not be profitable. Only when domestic producer prices plus market costs are lower than the export parity price of the same product does it become profitable to export.

The model does not capture bilateral trade flows across subnational regions, although it does identify subnational regions as being food surplus or deficit by comparing regional level demand and supply for total food commodities. Although producers and consumers in different regions operate in the same national markets for specific commodities, prices can vary across regions owing to differences in transportation and market costs. For example, in the Ethiopian EMM model, domestic marketing margins are defined at the regional level according to the distance to Addis Ababa, which represents the central market for the country. For a food surplus region, food crop prices faced by local producers are equal to the prices in the central market subtracting market margins, while for a food deficit region local prices are higher than those in the central market owing to marketing margins.

To analyze the growth–poverty effect, the nationally defined poverty line is adopted in the models rather than using the World Bank's dollar-a-day measure. National poverty lines are typically measured by total household expenditure, since household income is often significantly underreported in developing countries. However, changes in the representative households' expenditures in the EMM and CGE models are the results of changes in their incomes (that is, both expenditures and incomes are endogenous variables in the models).

A microsimulation model is used to capture detailed household consumption patterns. More specifically, all sampled households in the household living standard and monetary survey are used to construct the microsimulation model that links with their corresponding representative consumers in the EMM model, which in turn are defined across subnational regions and for both rural and urban areas. A top-down linkage is defined from the EMM model to the microsimulation model. For example, if the results from Ethiopian EMM model find that a 1 percent increase in GDP causes 1.3 percent increase in annual spending on teff for the household in the EMM model representing the Ethipoian region "rural West Tigray," then there will be 1.3 percent increase in spending on teff by each of the 143 sample households it represents in the microsimulation model. However, the share of teff in each of the 143 households' total expenditure varies. Therefore, 1.3 percent increase in teff expenditure will affect each of the 143 households differently depending on the share of teff in their consumption basket. As a result, the effect on total household expenditure will be larger for households spending a larger share of their income on teff. These differential effects occur across all commodities in the EMM model. According to these differential effects, the EMM-microsimulation models are able to estimate national or regional income distributional change.

In general, because of the larger share of staple food in poor households' budgets, the same income elasticity for all rural households can result in different aggregate effects on total expenditures across households. Given a fixed poverty line defined by real expenditure, some poor households whose per capita expenditure is initially below the poverty line may move out of poverty in certain years if their expenditure rises above the poverty line. Using the microsimulation model, the national poverty rates are recalculated according to updated total expenditure for each sample household for each year in a simulation.

Specification of the CGE Model. The growth–poverty relationship is examined in Uganda and Zambia using CGE and microsimulation models. As mentioned earlier, an important factor determining the contribution of agriculture and industry to overall economic growth are the linkages between these sectors and the rest of the economy. The proponents of agriculture argue that agriculture has strong growth linkages. Consumption linkages are captured in the CGE model by defining a set of nested constant elasticity of substitution (CES) production functions that allow producers to generate demand for both factors and intermediates. Moreover, the CGE models capture both forward and backward production linkages between agricultural and nonagricultural sectors. To reflect the heterogeneity of producers in Uganda and Zambia, the models are calibrated to highly disaggregated social accounting matrices (SAMs) that distinguish between producers in different sectors and regions, and the various commodities that they produce. As in the EMM models, these commodities are traded within national markets (that is, the model does not explicitly capture interregional trade). The model differentiates the factors of production, including capital and subnational region-specific land and labor. Labor is disaggregated across regions, gender, and education. Land and labor are fully employed, earn flexible returns under fixed supply, and are mobile across sectors. Regional labor markets allow low-skilled workers to migrate within but not across regions. By contrast, higher-skilled workers are mobile across regions. Capital is sector specific and earns flexible activity-specific profits. The detailed specification of production and factor markets in the models allows them to capture the changing scale and technology of production across sectors and subnational regions, and therefore how changes in a country's structure of growth influences its distribution of incomes.

Another area of the debate on the role of agriculture and industry relates to international trade. Some suggest that import competition may have undermined the growth linkages of agriculture and that food imports reduce the need for investment in domestic agriculture. The CGE models capture both import competition and export opportunities 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 (CET) function, while substitution possibilities exist 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.

A third area in the debate concerns the relative importance of agriculture and industry in generating household livelihoods and how this has changed over time. Income and expenditure patterns vary considerably across households, especially across geographic regions and rural and urban areas. These differences are important for distributional change, since the incomes generated by agriculture and industry will accrue to different households depending on their location and factor endowments. To capture these differences, the CGE model follows the EMM model by distinguishing between different representative households, each of which is an aggregation of a group of households in the underlying household living standard and monetary survey. Households in the CGE model receive income through the employment of their factors in both agricultural and nonagricultural production, and 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). As with the EMM model and to retain as much information on households' income and expenditure patterns as possible, the CGE model is linked to a microsimulation module based on the household survey. Endogenous changes in each commodity's 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 via this updated expenditure measure.

The models make a number of assumptions about how the Ugandan and Zambian economies maintain 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 governments cannot simply increase foreign debt but have to generate export earnings to pay for imported goods and services. Although 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 negative crowding-out effects of falling government revenues when the structure of growth shifts toward lower tax paying sectors such as agriculture.

Finally, the CGE models are recursive dynamic, which means that some exogenous stock variables in the models are updated each period based on results from previous periods. The models are run over the period to 2015, with each equilibrium period representing a single year.[11] The models also capture exogenous demographic and technological change. Changes in the population, labor supply, human capital, and total factor productivity (TFP) are based on projections that account for the effects of HIV/AIDS on labor supply, productivity, and household populations. 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, the CGE models incorporate distributional change by (1) disaggregating growth across provinces and sectors, (2) capturing employment effects through factor markets and price effects through commodity markets, and (3) translating these two effects onto each household in the survey 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 procedure allows the models to capture the distributional change associated with growth in agriculture and industry.

Agricultural Growth Is More Pro-Poor than Is Industrial Growth

A baseline scenario is first simulated in which the five case study countries are assumed to continue growing according to current trends until 2015. These trends include not only the level of aggregate economic growth but also its sectoral composition.[12] It is widely understood that most African countries are unlikely to meet with the first Millennium Development Goal of halving poverty by 2015 unless their growth performance improves dramatically. Taking Ethiopia as an example, the model's baseline scenario shows that if the current level and composition of growth are maintained, then the poverty headcount rate is likely to remain unchanged at around 44.3 percent by 2015 (cf. Table 3.4). Ethiopia therefore needs to not only accelerate the level of growth, but also find ways in which to enhance the "pro-poorness" of growth. In other words, it

[11]The Ugandan and Zambian models are calibrated to 1999 and 2001 SAMs respectively.

[12]The CGE models are calibrated further to match observed trends on the demand side of growth and for key macroeconomic indicators (for example, physical/human capital accumulation, current account changes, and terms-of-trade).

Table 3.4 Comparison of staples and exportable agricultural growth scenarios

	Baseline scenario	Staple-crops-led scenario	Export-crops-led scenario
Ethiopia (2003–15)			
Annual per capita GDP growth rate (%)	0.5	2.4	2.4
Annual GDP growth rate (%)	3.1	5.0	5.0
Agriculture	2.5	5.0	5.0
Staple crops and livestock	2.0	5.0	1.9
Export crops	4.0	4.4	18.0
Poverty headcount by 2015 (%)	44.3	27.2	31.6
Difference in poor population in 2015 (1,000)		–15,279	–11,313
Poverty–growth elasticity	NA	–1.80	–1.40
Ghana (2003–15)			
Annual per capita GDP growth rate (%)	2.2	3.4	3.4
Annual GDP growth rate (%)	4.7	6.0	6.0
Agriculture	4.6	7.7	7.7
Staple crops and livestock	4.6	8.5	3.7
Export crops	4.1	3.4	18.4
Poverty headcount by 2015 (%)	23.7	14.0	22.9
Difference in poor population in 2015 (1,000)		–2,615	–211
Poverty–growth elasticity	–1.50	–2.10	–1.10
Uganda (1999–2015)			
Annual per capita GDP growth rate (%)			
Annual GDP growth rate (%)	5.2	6.4	6.4
Agriculture	5.1	7.7	7.9
Staple crops	5.1	9.0	5.0
Export crops	4.4	–1.6	19.7
Poverty headcount by 2015 (%)	27.8	18.6	19.0
Difference in poor population in 2015 (1,000)		–3,602	–3,445
Poverty–growth elasticity	–0.98	–1.40	–1.39
Zambia (2001–15)			
Annual per capita GDP growth rate (%)			
Annual GDP growth rate (%)	4.0	5.0	5.0
Agriculture	4.6	7.8	7.1
Staple crops	4.1	7.9	4.0
Export crops	10.2	6.9	22.8
Poverty headcount by 2015 (%)	68.3	59.2	62.0
Difference in poor population in 2015 (1,000)		–1,210	–842
Poverty–growth elasticity	–0.35	–0.57	–0.47

Source: Authors' simulations and calculations.
Note: Rwanda is not included in the export crop growth simulation.

needs to identify the kind or composition of growth that is most effective at reducing poverty and that raises the poverty–growth elasticity. In the context of the current debate, it is necessary to consider the relative importance of agriculture and industry in helping Africa achieve its development objective of significantly reducing poverty.

The models are used to examine how differences in the structure of growth in each of the five case study countries influence the rate of poverty reduction. More specifically, two simulations are presented in which agricultural and industrial growth are accelerated separately and the effectiveness of this additional growth in reducing poverty is compared. To make the results comparable, poverty–growth elasticities are calculated for each scenario in the five countries.[13] Table 3.3 shows that the poverty–growth elasticity is consistently larger when additional growth is driven by agricultural rather than nonagricultural sectors. Again taking Ethiopia as an example, a 1 percent annual increase in per capita GDP driven by agriculture-led growth leads to 1.66 percent reduction in the poverty headcount rate per year. By contrast, a similar increase in per capita GDP driven by nonagricultural sectors leads to only a 0.73 percent fall in the poverty rate. These disparities in poverty–growth elasticities can translate into significantly different reductions in the poverty headcount over time. For example, with similar GDP growth, the poverty headcount in Ethiopia falls to 26.5 percent under the agricultural-led growth scenario compared with 37.3 percent under the nonagriculture-led growth scenario. Given its larger impact on poverty, agriculture-led growth in Ethiopia lifts an additional 9.6 million people out of poverty compared to nonagriculture-led growth, despite the fact that overall GDP grows at the similar rate under the two scenarios. These findings are consistent across the five countries studied. Given a similar GDP growth rate, the calculated poverty–growth elasticities are always higher under the agriculture-led scenario. However, the magnitudes of these differences vary across countries.

The poverty–growth elasticities are endogenous outcomes from the model results. Growth affects individuals differently owing to heterogeneity across regions and households. With different income sources and locations within a country, changes in income and consumption across households differ considerably from average changes at the national level (that is, per capita GDP or total consumption). To capture growth–poverty linkages *within* a country, it is necessary to capture changes in the distribution of incomes, which are determined primarily by country-specific initial conditions. For example, in some countries, agriculture generates a large share of national GDP and many households live in rural regions dominated by agriculture. For these households, participation in agricultural activities is often the major source of income, and hence they are likely to benefit more from agriculture-led growth than nonagricultural growth. Households with greater opportunities to work in the urban sector or who can take advantage of nearby city markets to produce higher-value agricultural products, may concentrate closer to urban centers and be better positioned to benefit from nonagricultural sectors or export agriculture. Since such households are usually less poor than remoter households, economic growth driven by nonagricultural sectors may have less impact on poverty reduction. For example, according to the Rwandan national household survey conducted in 2000–01, agriculture accounts for 50 percent of household income at the national level, whereas it accounts for 75 percent for the average poor household. The importance of agricultural incomes is even higher in poorer regions of the country. Under such circumstances, agricultural growth is expected to be more pro-poor than nonagricultural growth be-

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[13]The poverty–growth elasticity used in this study measures the responsiveness of the poverty rate to changes in the per capita GDP growth rate. The formula for this elasticity is:

$$\frac{\Delta P0/P0}{\Delta GDPpc/GDPpc} = \frac{\Delta P0}{\Delta GDPpc} \cdot \frac{GDPpc}{P0},$$

where ΔPO and $\Delta GDPpc$ are average annual changes (from the base year) in the poverty headcount *rate* and *level* of per capita GDP; and $P0$ and $GDPpc$ are the base-year poverty headcount rate and per capita GDP. The poverty–growth elasticity measures the percentage change in the poverty headcount rate caused by a 1 percent increase in per capita GDP. This is not equivalent to a percentage point change in the poverty headcount rate.

cause it is a more important income source for the poor.

Agricultural growth can also benefit urban and landless or net food-buyer rural households if rising agricultural productivity lowers food prices. This reduction in price is particularly important for poor urban and rural households for whom food purchases are major items in their expenditure baskets. For example, Ethiopia's 1999–2000 national household survey showed that poor urban households on average spend more than 50 percent of their total income on staple foods, which is higher than the corresponding 30 percent for all urban households.

Therefore, the initial conditions in each country are the primary factors determining the size of the poverty–growth elasticity. However, it should be noted that the models' assumptions can also affect this elasticity, given that it is calculated ex ante from the model simulations (as opposed to ex post estimations from survey data). For example, the assumption on the labor market (that is, labor mobility across regions and between rural and urban areas) can affect whether growth is shared by a majority of the population. Assuming perfect labor markets and full employment implies that rural households, whether they are poor or not, can equally benefit from urban growth by migrating to urban areas and participating in urban-based nonagricultural sectors. If there are imperfect labor markets in certain regions, especially those dominated by rural areas, then poor or rural households have fewer opportunities to participate in urban-based growth.[14] Admittedly, these assumptions, which are often country specific, make it more difficult to compare results across the five countries. However, it is reasonable to compare the poverty–growth elasticities produced by the models within a country, since these scenarios are conducted using the same model, poverty line, and underlying assumptions.

The large gap between the poverty–growth elasticities in the two scenarios reported in Table 3.3 indicates the relative importance of agricultural growth, especially for poorer rural households. The proponents of agriculture suggest that the large size of the agricultural sector in most African countries means that this sector is able to contribute significantly to aggregate growth. However, a small agricultural share of GDP, as is the case in Zambia, does not imply that the agricultural sector is less important for generating pro-poor growth. Zambia's economic structure partly reflects the country's long-standing dependence on copper production and exports, which has fostered a dual economy biased in favor of urban-based industrialization. Copper mining is a capital-intensive enclave industry with few backward linkages to rural areas. Therefore, growth driven by this sector does not provide the magnitude of poverty reduction needed in this impoverished country. The model simulations for Zambia show that growth in the nonagricultural sector, even including the non-mining industrial sectors, is less effective at reducing poverty than an agricultural-led growth strategy. As seen in Table 3.3, growth in the nonagricultural sector would reduce poverty to 64.4 percent by 2015 compared with 58.9 percent by the same year under an agriculture-led growth scenario.

Broad-Based Agricultural Growth Is More Pro-Poor than Is Export-Led Growth

In recent years, traditional and nontraditional export agriculture has grown rapidly in many African countries, and these high-value crops have often received the most policy support from the governments. In Ghana, for example, the cocoa sector has historically received considerable support, despite the higher prevalence of poverty among food crop farmers. Even with the agricultural reforms implemented at the end of the 1980s, the

[14]Detailed descriptions of the assumptions underlying the various models are provided in the appendix.

cocoa sector has still received priority attention over food crops. Although such high-value agriculture may have greater potential for growth, its contribution to overall economic growth may not be sufficient within the foreseeable future, given its small initial base in most African countries. Moreover, growth in high-value export crops may only reach those farmers with better urban and/or foreign market access and will therefore have little impact on the food costs of the poor.

In Ethiopia, cereals, pulses, root crops, and oil crops make up almost 65 percent of agriculture. Along with livestock production, a majority of Ethiopia's poor depend heavily on cultivating these staple crops. The same is true in Rwanda, where the share of staple crops and livestock in the agricultural sector's total output is as high as 90 percent. By contrast, the shares of staples and livestock in the other three case study countries are relatively low, but are still as high as 70 percent of Ghana's agricultural total output, 54 percent in Uganda, and 65 percent in Zambia.

The degree to which different agricultural subsectors can contribute to growth and poverty reduction varies considerably. This subsection evaluates two broad groups of agricultural subsectors in terms of the effectiveness of their growth to reduce poverty: staple crops and livestock, and traditional and nontraditional export crops. An empirical method is used that utilizes the economywide models which determine the poverty reduction resulting from accelerating growth in each of the two sectors.

Assuming similar growth rates at the subsector level, greater economywide growth will obviously be generated by the larger subsector, in turn producing a (generally) larger effect on poverty. On the other hand, small subsectors, such as nontraditional export crops, may have greater capacity to grow rapidly and may require lower levels of investment 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. To ensure that the two simulations are comparable despite having different initial contributions to GDP, it is necessary to accelerate growth in each subsector until a similar growth rate is achieved at the aggregate level. Taking Zambia as an example, for export crops alone to generate an additional 1 percent annual growth in aggregate GDP (that is, from 4 to 5 percent), the shares of these crops would have to grow at 23 percent per year because this subsector is initially very small (see Table 3.4). By contrast, the staples sector is substantially larger and so does not have to grow as rapidly to achieve the same additional 1 percent annual growth in GDP. Similarly, to achieve 5 percent growth in annual agricultural GDP in Ethiopia, the required growth rate for the staple crops is 5 percent if additional agricultural growth is driven by these crops alone. However, it requires 18 percent annual growth for export crops to achieve the same agricultural growth rate. Such high growth requirements for export crops are valid in each of the five case study countries. Although these sectors undoubtedly have considerable growth potential, it is reasonable to question whether such high growth rates in any agricultural subsector are feasible over a sustained period of 10 to 15 years.

Growth in staple crops is not only necessary for agricultural and overall economic growth, but it also can lead to strongly pro-poor outcomes because of its broad base. The model simulations show that even if extremely high growth in export crops is possible, it leads to much smaller poverty–growth elasticities. For example, if the same 5 percent agricultural GDP growth rate in Ethiopia is driven by the staples sector, then the national poverty rate is likely to fall to 27 percent by 2015. This is 4.4 percentage points lower than the poverty rate expected under the agricultural-export-led scenario with a similar agricultural growth of 5 percent. Therefore, despite generating the same aggregate growth rate, accelerated staples-led growth will be able to lift an additional 4 million people out of poverty by 2015.

Even though growth in Africa's staples sector can play a critical role in reducing poverty, past growth in this sector has typically arisen from area expansion. Many African countries were considered self-sufficient in food crop production until the 1970s and there seemed to be no pressing need to pay special attention to the food sector. With no permanent food problem and with virgin lands still available in most countries, the pressure to change established ways of production (and accompanying social institutions) was low. The situation has changed dramatically over the past three decades. Africa's population has quadrupled since the 1950s and is projected to more than double between 2000 and 2050. Expansion of arable land has stagnated in recent years, indicating that land frontiers may have been reached (Sida 2006). The result is mounting population pressure and declining farm sizes. The land constraint has become more serious in the countries such as Ethiopia and Rwanda, where the distribution of land among a majority of small farms appears to be worse than those of many Asian countries at the time of their green revolutions.

It is reasonable to argue that in such a situation, intensification of food agriculture ought to take place. However, so far extensification has still been a more practical option in large parts of Africa. An extensive literature identifies the key factors capable of increasing staple sector productivity. Many studies find that declines in the provision of credit from the banking sector and low accessibility to modern inputs are among the main factors affecting incentives to intensify farming. These constraints often arise when input subsidies are removed during liberalization and are not replaced by appropriate market-oriented institutions and policy instruments. Such problems tend to be more serious in more remote rural areas dominated by subsistence production. For example, the population in Ghana's arid rural savannah relies almost entirely on subsistence production with little agroprocessing, few opportunities for diversifying into nonfarm income, and weak infrastructure. Therefore, despite relatively high levels of national growth in Ghana, this region experienced only a slight decline in its poverty headcount.

A number of survey-based studies have identified the potential for the intensification of food crop production in Africa. In each of the five case study countries, there is evidence of farms or regions that have achieved crop yields substantially above the national average. For example, based on a survey of 13,000 rural households in Ethiopia, we found the highest maize yield to be around 7.8 tons per hectare and that 5 percent of households generated yields twice the national average of 1.8 tons per hectare. Sida (2006) conducted surveys of 3,000 smallholders in eight African countries (including Ethiopia, Ghana, Uganda, and Zambia) and showed yields as high as 10 tons per hectare for maize, 3.5 tons per hectare for rice, 2 tons per hectare for sorghum, and 16 to 28 tons per hectare for cassava (Sida 2006: 37). Further, a number of countries have experienced significant increases in land productivity at the national level, such as in Burkina Faso, where major food crops yields have risen dramatically over the last 40 years. Many other studies in Africa support the finding that intensification has occurred in certain regions and among certain categories of farmers (Turner, Hyden, and Kates 1993; Snrech 1995; Wiggins 2000; Gabre-Madhin and Haggblade 2001; Haggbalde et al. 2003). Therefore, although Africa has not achieved its green revolution, there are numerous examples where the intensification of food crop production has been achieved.

Transforming individual success stories into broader agricultural development remains a challenge. Several studies have identified preconditions for agricultural transformation—the most important of which is ensuring the commitment of African governments to invest in agriculture. Since its inception, the Africa Union (AU) has placed agriculture at the top of its agenda. The seriousness of this commitment is reflected in its urging member states to increase annual allocations to agriculture to at least 10 percent of national budgets and in its approval of the Comprehensive Africa Agriculture Development Program (CAADP) under the New Partnership for Africa's Development (NEPAD). However, regional commitments need to be realized at the country level to achieve the agricultural growth necessary to significantly reduce poverty and encourage economic transformation.

Innovations in science and technology are both a precondition and a part of agricultural transformation. African farmers need technologies applicable to their diversified agroecological conditions to counter erratic rainfall and declining soil fertility. While technologies suitable for African agriculture are crucial to shift agricultural growth from land expansion to intensification, Africa's green revolution should not overly rely on a "package of technology." This is an incorrect interpretation of Asia's green revolution, where the private sector and smallholders played important roles (Sida 2006). Agricultural intensification also involves the development of supply chains around smallholder farmers, such as the presence of input markets, seasonal finance, and marketing systems to increase farm production and deliver goods to consumers at competitive prices (Poulton et al. 2006). A lack of profitable opportunities in food production for small-scale agriculture will deter the private sector during the earlier stages of development. As such, to reduce costs and mitigate risks, public investments are needed in agricultural research and in market and institutional development. There is broad agreement that increased investment in key public goods is required to revitalize agricultural development. For most African countries, however, public investment is still a small share of the government's budget—a share that has remained stagnant or even declined over the past decade (Fan and Rao 2003). For Sub-Saharan Africa as a whole, agricultural spending accounted for only 2.8 percent of total government spending in 2004, which falls far short of the 10 percent target identified by African leaders in the 2003 Maputo Declaration. This share has also declined from 3.2 percent in 1994.[15] Further, the gap between Africa and other parts of the developing world is even wider if we consider the ratio of agricultural spending to agricultural GDP. This ratio was 5.3 percent for Africa as a whole in 2004, whereas it was 11.2 percent and 6.2 percent in Asia and Latin America, respectively.

The positive role of public investments in agricultural research and development and in rural infrastructure on the agricultural growth has been econometrically estimated. Drawing on 294 studies that estimate the returns to agricultural research and development (including extension), Alston et al. (1998a) found a wide range of rates of return to research, but that the annual rate averaged 73 percent. Evidence from rural Uganda indicates that public investment in agricultural research had the highest impact on poverty reduction during the 1990s (Fan and Rao 2004). In addition to financial resources, agricultural innovation requires human capital, and therefore sustaining and improving on advances in agricultural research requires concurrent investments in general education (Hayami and Ruttan 1985).

Public investment in rural infrastructure is also necessary to increase consumer demand and farmers' access to input and output markets, stimulate the rural nonfarm economy and rural towns, and more fully integrate the poorest regions into their countries' economies. Spencer (1994) estimated

[15]On the other hand, agricultural spending accounted for 8.1 percent of total government spending for Asian developing countries as a whole in 2004.

the density of rural roads in Africa to be well below that of Asia at the time of its green revolution. Substantial investments are therefore needed to raise roads and other basic rural infrastructures to the levels required for agricultural development (U.N. Millennium Development Project 2005). As Fan, Zhang, and Rao (2004) showed in rural Uganda, infrastructure investments do not have to be excessive to have sizeable impacts. Indeed, investments in feeder roads reduced the number of poor Ugandans by more than three times as much as investments in more costly murram or tarmac roads. Public investment in rural infrastructure also demonstrates a "crowding-in" effect on private investment, which, in the absence of rural infrastructure, is much less profitable (Timmer 2002). The importance of infrastructure is supported by the Ethiopian and Zambian economy-wide models, which suggest that if agricultural growth is combined with a lowering of transaction costs through public investments, then poverty reduction would be substantially improved (Thurlow and Wobst 2004; Diao et al. 2005). Reducing marketing costs benefits smallholders primarily 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. As a result of these cross-sector linkages and positive price effects, not only can growth in the agricultural sector be stimulated, but in addition the pro-poor effect of the resulting growth is much stronger in rural areas where the infrastructure and market conditions are especially poor.

CHAPTER 4

Conclusions

Economic theory, cross-country empirical studies, and the success of the green revolution in Asia all confirm that agriculture can play a critical role in the development process. Indeed, in much of the development literature, agricultural growth has been viewed as a precondition for industrialization because the sector provides surplus labor to industry, savings for capital investment in nonagricultural sectors, and more food to meet the increasing demand of a growing nonagricultural labor force, without which labor costs in the industrial sector must rise. As agriculture is the largest employer in most developing countries, growth in the sector also has a large impact on poverty reduction by creating income opportunities for the poor in both the farm and nonfarm economy while lowering food prices for poor rural and urban consumers. By increasing food security, agriculture also improves nutrition and in turn promotes productivity. At the same time, it decreases a country's dependence on imported food, which often cannot be obtained without sufficient and stable levels of foreign exchange. Finally, the unique decision-making processes associated with smallholder agriculture can stimulate broader growth by fostering the processes of learning and innovation.

The pro-growth and pro-poor performance of agriculture depends on the broad participation of small farmers. Small farms dominate agriculture in many developing countries, and the transformation from traditional to modern agriculture is based on the efficiency of small farms and their transformation from subsistence to market activities. In an increasingly globalized world, however, small farms face a number of new challenges in terms of accessing market opportunities. Particularly in Africa, where an agricultural transformation comparable to Asia's or Latin America's has yet to occur, there is skepticism about whether an agriculture-led strategy in general, and a small farms one in particular, is a viable approach. Nevertheless, there is little evidence or theory in the African context for the superiority of alternative strategies, such as developing large-scale commercial agriculture, bypassing agriculture straight to industrialization, or encouraging a mass migration from rural to urban areas. Indeed, proponents of such strategies fail to explain how they will tackle the rising food costs and high urban un- and underemployment that would inevitably result in countries with small and insulated industrial sectors.

The importance of agriculture as a driving force for African development is highlighted in the typology presented in Table 3.1. More than 70 percent of low-income African countries have favorable agricultural conditions, and agriculture comprises more than a third of GDP in two-thirds of these countries. Even in countries where agriculture is a smaller component of GDP, smallholder farming often represents the dominant livelihood for the poorest households. By examining the experience of five countries during the 1990s, some commonalities emerged despite variations in the countries' development levels and mineral resource endowments. Confirming much of the development theory discussed in Chapter 2, agricultural growth in these countries creates greater linkages and hence generates more poverty reduction than growth in the nonagricultural sector alone. Overall, however, increased productivity in agriculture and nonagriculture together offers the greatest prospects for generating broad economic development and decreasing poverty.

Although much of the early development theory did not examine variations in growth and poverty-reduction potential within the agricultural sector, these differences were evident in the case studies. Growth in traditional and nontraditional, high-value exports can significantly contribute to farmers' incomes in areas with good irrigation and convenient access to market centers. Yet, in all five countries, growth in food staples consistently offered greater poverty reduction than any of the other subsectors did. For most African countries, especially those with large populations, agricultural and broader economic growth will depend on growth in domestic markets. In this regard there is evidence that domestic demand for staple foods, which provide the bulk of that market, will double over the next 15 years (Diao and Hazell 2004). Increases in farm incomes obtained by taking advantage of this market opportunity will be greater than those offered by niche markets.

Policy Implications

Many of the arguments for promoting agricultural development are based on evidence showing this is an efficient strategy for economic growth, especially in countries at early stages of development. Small farms are also considered more efficient than large farms in countries with a surplus of labor but a scarcity of land and capital, whereas labor is often more costly in more developed economies.

Where agriculture and small farms are most efficient, their development can be a "win–win" solution for increasing growth and reducing poverty. In such situations, an obvious policy implication is for governments to stand back and let market forces hold sway in driving agriculture and small farm development. In theory, this policy should ensure that the most efficient types of agriculture, commodities, regions, and farm sizes prevail. The primary role of policy interventions should be to provide an enabling economic environment for market-led development, which typically involves providing stable and undistorted economic incentives and essential public goods and services.

Although widely favored in much contemporary development thinking, this "hands-off" approach ignores the presence of institutional and market failures that affect disparate groups and regions differently, preventing the most efficient market outcomes from being realized. For example, if market failures favor large farms over small in accessing markets and inputs, then unfettered markets may generate outcomes dominated by large farms that are less efficient and less equitable than alternatives. Similar issues arise when market and institutional failures favor manufacturing over agriculture in countries that have a primary comparative advantage in agriculture. As such, targeted policy interventions that correct these underlying market failures might increase efficiency and equity, leading to "win–win" outcomes.

Another reason for targeted policy interventions in the agricultural sector arises when growth must be balanced against poverty or other social goals. There is less debate about socially-oriented public investment since market solutions to provide efficient outcomes are not necessarily equitable or poverty reducing outcomes. However, growth-oriented investment in agriculture and rural economy can become a more effective alternative in poverty reduction than such subsistence-oriented direct support. For example, food aid, a common response to distress from donors, typically costs more than US$250 for each ton of cereals delivered in rural areas, compared to typical smallholder production costs of US$100 or less (Sukume et al. 2000). Obviously, this will not always be the case and the efficiency of public investment in agriculture is also constrained by many other conditions. Moreover, one also needs to be concerned that public investment or support policies for nonviable small farms do not encourage too many workers and poor people to stay in agriculture or for too long. In these cases, investment in agriculture and small farms may compete with investing in scarce resources in other sectors that may be more efficient in stimulating the economic transformation, such as investment in human capital and in institutional and social capital.

It is also important to consider that public interventions are not without cost, nor do governments necessarily have the capacity to intervene effectively in the ways they desire. A key question for any intervention is whether the net economic and social benefits of intervening are sufficient to justify the costs. This is a particularly important question for small farm development strategies that require investment in public infrastructure and services over large rural spaces, and effective but spatially dispersed rural institutions. This strategy might be much more costly and challenging than some urban-based development strategies and must be justified on the basis of significant win–win benefits.

Context is also very important when thinking about appropriate interventions to assist farmers. Countries with dynamic and growing national economies and rising per capita incomes offer farmers many more opportunities to diversify into higher value products or nonfarm sources of income or to exit farming. But in poorer and slower growing economies, opportunities for income diversification and exit strategies are much more limited. Assisting farmers in countries or regions with limited agricultural potential is also likely to be more costly and less effective than in areas with good potential, and may need to be undertaken as part of a managed exit strategy for many farmers. Clearly, a one-size-fits-all approach will not work across all situations.

African agricultural development involves a number of key policies. First, product and input markets need to provide efficient outcomes. Because it is unrealistic to expect that the private sector alone can, in the short-term, offer the necessary levels of marketing and input services, there is a need for greater public sector involvement in many African countries than is currently fashionable. The challenge is to develop new institutional arrangements between the public and private sectors that can foster private sector development and investment without leaving farmers in the lurch during the transition. Interventions in land tenure systems to provide smallholders with more equitable and secure access to land as well as the development of flexible land markets are part of institutional innovation. Second, because small farmers face an increasingly tilted playing field, their ability to attain a viable future depends on improving infrastructure and education, distributing key technologies and inputs, and promoting producer marketing organizations that can link small farmers to the new market chains. Small farmers cannot do all these things on their own, and the public, private, and nongovernmental organization sectors all have important roles to play. Third, synergies with the nonfarm sector should be fostered. Investing in the human and financial assets of the rural poor are important for enhancing the latter's access to productive nonfarm employment and thereby help them find viable exit strategies from agriculture as their economies grow. Finally, safety nets should be established for those households unable to adapt, or who slip into poverty as a result of risks that they cannot manage. Indeed, although agricultural growth can make deep inroads into poverty and hunger in many poor countries, vulnerability to production and market shocks will still persist. Vulnerability is particularly severe for rural households during times of crisis and when confronted with chronic diseases, such as HIV/AIDS. By involving local communities in the design and delivering of assistance, there have been real advances in recent years in targeting assistance in an efficient manner that corresponds to local needs and constraints.

There is both cause and evidence to counter pessimistic views about the future of smallholder agriculture in Africa. As highlighted by Gabre-Madhin and Haggblade (2004), African agriculture has enjoyed notable successes in advancing research and development, improving environmental conservation techniques, and seizing new market opportunities. Moreover, many of the public investments and policies needed to encourage agricultural development are also essential for stimulating growth in sectors outside of agriculture. Therefore, although many new challenges face African agriculture today, the continent has the capacity to tackle them, thereby releasing millions of people from poverty.

Appendix: Mathematical Specifications of the Models

Two different types of models are used in this study: economywide multimarket (EMM) models (Ethiopia, Ghana, and Rwanda) and computable general equilibrium (CGE) models (Uganda and Zambia). However, the models of the five case study countries differ according to both their specification and the disaggregation of the data used to calibrate them. This first section of the appendix identifies the different sectors and commodities used in the models, while subsequent sections review the general specifications of the EMM and the CGE models. Sectoral and institutional structures of both models are summarized in Table A3.

Mathematical Specification of the EMM Models

Supply Functions

Yield Function (for crops)

$$Y^q_{R,Z,i,t} = YA^q_{R,Z,i,t}\, P_{R,Z,i,t}^{\alpha^q_{R,Z,i}}, \tag{1}$$

where $Y^q_{R,Z,i,t}$ is the yield for crop i with technology q in region R and district (or zone in the case of Ethiopia) Z at time t, and $P_{R,Z,i}$ is the producer price for i and can be different across regions or zones. $Y^q_{R,Z,i,t}$ is the productivity shift parameter, which varies according to different technologies q. $YA^q_{R,Z,i,t}$ could be estimated as a function of modern inputs, such as irrigation, fertilizer, and improved seed, were more data available. Currently, only the Ethiopian model captures the mean difference across technologies, while there is no such information on technology difference in the models for the other countries. In the case of the Ethiopian model, 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 $YA^q_{R,Z,i,t}$, which changes over time:

$$YA^q_{R,Z,i,t+1} = YA^q_{R,Z,i,t}(1 + g_{Y_{R,Z,i}}), \tag{2}$$

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

Area Function (for crops)

$$A^q_{R,Z,i,t} = AA^q_{R,Z,i,t}\prod_j^J P_{R,Z,j,t}^{\beta_{R,Z,j}}, \text{ and } \sum_j^J \beta_{R,Z,j} = 0, \tag{3}$$

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

Table A1 The structure of poverty and production in Sub-Saharan Africa, 1999

				Share of population or GDP (%)				
Region	Number of countries	GDP p.c. (1995 US$)	Poverty headcount	Total population	Poor population	Rural population	Agriculture to GDP	Industry to GDP
Sub-Saharan Africa	42	865	50.7	100.0	100.0	63.5	29.3	28.0
Middle-income countries	8	2,996	26.4	7.8	0.8	49.8	8.4	42.6
Botswana		4,130	22.0	0.3	0.1	50.6	2.4	46.7
Cape Verde		1,550	27.3	0.1	0.0	36.7	11.0	16.8
Equatorial Guinea		1,578	31.7	0.1	0.0	50.8	8.5	87.0
Gabon		4,378	23.0	0.2	0.1	17.8	7.6	50.6
Namibia		2,383	33.9	0.3	0.2	68.6	11.3	32.7
Mauritius		4,352	5.0	0.2	0.0	58.4	6.3	31.2
South Africa		4,068	2.0	6.6	0.2	42.4	3.2	31.2
Swaziland		1,529	66.0	0.2	0.2	73.3	16.8	44.4
Low-income countries	34	363	56.4	92.2	99.2	66.7	34.2	24.5
More favored agriculture	26	386	55.2	82.3	88.6	64.8	33.2	26.3
Coastal countries	10	383	40.8	21.7	15.1	63.0	33.5	19.6
Benin		424	16.4	1.0	0.3	57.0	35.5	14.4
Côte d'Ivoire		715	13.5	2.5	0.6	56.0	24.3	21.6
The Gambia		382	37.8	0.2	0.1	68.7	39.6	14.2
Ghana		421	44.8	3.0	2.3	63.6	35.9	25.2
Guinea-Bissau		206	84.2	0.2	0.3	67.7	56.2	12.7
Kenya		325	23.9	4.7	1.9	65.7	19.0	18.2
Mozambique		213	32.6	2.8	1.5	66.8	22.0	25.8
Senegal		629	13.3	1.5	0.3	51.9	17.9	26.9
Tanzania		197	78.3	5.2	7.0	66.8	44.8	15.8
Togo		322	63.3	0.7	0.8	66.1	39.4	21.1
Landlocked countries	6	335	54.6	19.1	22.0	78.8	32.5	22.8
Burkina Faso		250	57.0	1.8	1.7	83.1	38.2	20.7
Ethiopia		121	85.2	10.0	14.6	84.1	52.3	11.1
Lesotho		563	40.9	0.3	0.2	71.3	16.3	42.0
Malawi		163	51.0	1.6	1.4	84.9	34.0	17.9
Uganda		355	40.8	3.5	2.4	85.5	36.4	20.9
Zimbabwe		559	52.4	2.0	1.7	64.0	17.6	24.4
Mineral-rich countries	10	420	70.1	41.4	51.5	58.1	33.3	35.0
Angola		525	72.2	2.1	2.5	65.2	8.0	66.8
Central African Republic		696	40.0	2.3	1.6	50.3	42.7	19.6
Cameroon		339	81.5	0.6	0.8	58.3	55.4	20.9
Democratic Republic of Congo		85	92.4	7.9	12.5	60.0	56.3	18.8
Republic of Congo		792	52.0	0.5	0.4	34.0	5.9	66.1
Guinea		613	64.0	1.2	1.3	72.0	24.4	37.7
Nigeria		257	67.6	19.8	22.8	55.1	29.5	46.0
Sierra Leone		158	71.8	0.8	1.0	62.7	50.1	29.8
Sudan		328	80.0	4.8	6.6	63.0	38.9	18.8
Zambia		405	79.3	1.6	2.1	60.2	22.1	25.6
Less favored agriculture	8	289	60.1	9.9	10.6	73.2	37.4	18.9
Comoros		433	55.5	0.1	0.1	66.2	40.9	11.1
Madagascar		253	45.9	2.4	1.9	69.9	29.8	14.5
Burundi		141	65.4	1.1	1.2	90.7	50.0	18.7
Mali		292	71.7	1.7	2.1	69.1	37.8	26.4
Rwanda		253	58.9	1.3	1.3	93.7	40.5	21.6
Chad		230	81.8	1.2	1.7	75.8	38.6	13.7
Mauritania		502	27.2	0.4	0.2	41.0	20.9	28.6
Niger		208	74.5	1.7	2.2	78.9	40.4	16.9

Source: Authors' calculations using World Development Indicators (World Bank 2003a) and UNIDO (2004) for 1999 dollar-a-day poverty rates.
Notes: Simple averages were used thus treating all countries equally regardless of population. Five Sub-Saharan countries are excluded because of data limitations (Eritrea, Mayotte, São Tomé and Principe, Seychelles, and Somalia). p.c. is per capita.

Table A2 Growth decomposition for African countries, 1985–1999

	Share of GDP (1999)			GDP growth rate (%)			Growth contribution (%)			
Region	Agric.	Ind.	Serv.	Agric.	Ind.	Serv.	Agric.	Ind.	Serv.	GDP growth
Sub-Saharan Africa	29.3	28.0	42.8	3.2	4.0	3.1	1.0	1.0	1.3	3.4
Middle-income countries	8.4	42.6	49.0	2.7	8.4	5.7	0.4	3.1	2.8	6.3
Botswana	2.4	46.7	50.9	2.6	5.3	13.5	0.1	2.8	5.9	8.8
Cape Verde	11.0	16.8	72.2	3.8	5.0	5.0	0.5	1.0	3.3	4.8
Equatorial Guinea	8.5	87.0	4.6	4.3	33.0	8.5	1.9	11.7	1.7	15.4
Gabon	7.6	50.6	41.7	0.0	2.5	2.3	0.0	1.2	1.0	2.2
Namibia	11.3	32.7	55.9	4.7	2.2	3.7	0.5	0.7	2.1	3.3
Mauritius	6.3	31.2	62.5	1.4	7.7	6.2	0.2	2.5	3.5	6.1
South Africa	3.2	31.2	65.6	3.3	0.6	2.2	0.1	0.2	1.3	1.7
Swaziland	16.8	44.4	38.8	1.8	10.7	4.1	0.3	4.4	1.8	6.4
Low-income countries	34.2	24.5	41.3	3.3	3.0	2.5	1.1	0.7	1.1	2.9
More favored agriculture	33.2	26.3	40.5	3.2	3.1	2.4	1.1	0.8	1.0	2.9
Coastal countries	33.5	19.6	46.9	3.5	4.1	3.3	1.2	0.7	1.5	3.5
Benin	35.5	14.4	50.0	5.4	3.7	2.9	1.9	0.5	1.5	3.9
Côte d'Ivoire	24.3	21.6	54.1	2.9	4.1	1.1	0.8	0.9	0.6	2.3
The Gambia	39.6	14.2	46.2	3.0	5.4	3.2	0.9	0.7	1.8	3.4
Ghana	35.9	25.2	38.9	2.7	5.0	6.5	1.1	1.1	2.4	4.6
Guinea-Bissau	56.2	12.7	31.1	3.6	0.8	3.1	2.0	0.1	1.0	3.1
Kenya	19.0	18.2	62.9	2.0	2.8	3.8	0.6	0.5	2.0	3.1
Mozambique	22.0	25.8	52.2	4.6	7.9	6.2	1.7	1.6	2.7	6.0
Senegal	17.9	26.9	55.2	3.3	4.7	3.3	0.6	1.0	2.0	3.6
Tanzania	44.8	15.8	39.4	3.5	2.8	2.9	1.6	0.4	1.1	3.1
Togo	39.4	21.1	39.4	3.7	3.6	0.4	1.3	0.8	0.2	2.3
Landlocked countries	32.5	22.8	44.7	3.6	4.5	4.3	1.3	1.0	1.8	4.1
Burkina Faso	38.2	20.7	41.1	4.2	4.0	4.7	1.5	0.9	2.0	4.3
Ethiopia	52.3	11.1	36.5	2.7	1.8	4.9	1.5	0.2	1.7	3.4
Lesotho	16.3	42.0	41.7	2.1	8.3	4.3	0.4	2.6	2.1	5.1
Malawi	34.0	17.9	48.1	5.5	3.0	2.9	2.2	0.7	1.1	4.0
Uganda	36.4	20.9	42.8	3.5	9.0	6.1	1.7	1.3	2.2	5.2
Zimbabwe	17.6	24.4	57.9	3.4	1.1	2.7	0.6	0.3	1.4	2.3
Mineral-rich countries	33.3	35.0	31.7	2.8	1.3	0.4	0.8	0.4	0.2	1.4
Angola	8.0	66.8	25.3	1.3	3.9	–0.4	0.2	2.1	–0.1	2.1
Central African Republic	55.4	20.9	23.7	2.8	1.2	–0.9	1.4	0.2	–0.3	1.3
Cameroon	42.7	19.6	37.7	3.7	–0.1	–0.5	1.2	0.0	–0.2	1.0
Democratic Republic of Congo	56.3	18.8	24.9	1.1	–6.1	–7.0	0.5	–1.4	–2.4	–3.3
Republic of Congo	5.9	66.1	28.0	2.2	2.0	0.0	0.2	0.9	0.0	1.2
Guinea	24.4	37.7	37.9	4.1	3.6	3.2	1.0	1.2	1.4	3.5
Nigeria	29.5	46.0	24.5	4.7	2.5	4.9	1.5	1.0	1.2	3.8
Sierra Leone	50.1	29.8	20.1	–3.5	–0.1	–1.2	–1.5	0.0	–0.4	–2.0
Sudan	38.9	18.8	42.4	6.6	6.0	4.1	2.6	1.0	1.8	5.4
Zambia	22.1	25.6	52.3	4.5	–0.3	2.2	0.9	–0.1	0.9	1.7
Less favored agriculture	37.4	18.9	43.7	3.5	2.7	2.6	1.3	0.5	1.2	3.0
Comoros	40.9	11.1	48.0	3.4	3.7	–1.0	1.3	0.4	–0.5	1.2
Madagascar	29.8	14.5	55.7	2.2	2.6	2.5	0.7	0.3	1.4	2.4
Burundi	50.0	18.7	31.3	1.4	0.8	1.8	0.8	0.2	0.5	1.4
Mali	37.8	26.4	35.9	4.1	6.8	2.1	1.8	1.2	0.8	3.8
Rwanda	40.5	21.6	37.9	3.2	1.8	3.7	1.3	0.3	1.5	3.1
Chad	38.6	13.7	47.7	5.8	3.3	3.8	2.1	0.5	1.9	4.4
Mauritania	20.9	28.6	50.5	3.9	2.6	4.5	1.0	0.8	1.9	3.8
Niger	40.4	16.9	42.7	3.7	0.3	3.6	1.4	0.0	1.6	3.1

Source: Authors' calculations using World Development Indicators (World Bank 2003a).

Notes: Aggregations across countries are simple-averages rather than GDP weighted averages. Although average GDP shares for 1985–2001 were used for decomposition, only the share for 2001 is shown, for consistency with other tables. Agric. is agriculture; Ind. is industry; and Serv. is services.

Table A3 Sectors, households, and regions in the models

Ethiopia	**Economywide Multimarket Model**
Agriculture	
Staple crops	Maize; teff; wheat; sorghum; barley; millet; oats; rice; potatoes; beans; peas; other pulses; groundnuts; rapeseed; sesame; other oil crops; domestic vegetables; bananas; other domestic fruits
Export crops	Exportable vegetables; other horticultural crops; chat; cotton; coffee; sugar; beverages and spices
Other	Bovine meat; goat meat and mutton; other meat; dairy products; poultry; fish
Nonagriculture	
Industry	Industry
Services	Services
Regions	56 nationally defined zones
Households	112 aggregate households representing rural and urban in 56 zones
Data sources	Agricultural Sample Survey, 1997/98–2000/01 (Central Statistics Authority)
	Agricultural Sample Enumeration, 2001/02 (Central Statistics Authority)
	Household Income, Consumption and Expenditure Survey, 1999/2000 (HICES)
	Ethiopia Statistical Abstract, 2003 (Central Statistics Authority)
	Statistical Database, 2004 (Ethiopian Economic Association)
	FAOSTAT (for agriculture) and World Bank (for sector GDP)
Ghana	**Economywide Multimarket Model**
Agriculture	
Staple crops	Maize; rice; wheat; sorghum and millet; cassava; yam; cocoyam; plantains; groundnut; beans
Export crops	Cotton; nuts; exportable vegetables; pineapple; coconut; other exportable fruits; sugar; cocoa bean; coffee; oil palm; tobacco; rubber; wood
Other	Domestically consumed vegetables; domestically consumed fruits; beef; poultry; mutton meat; pig meat; other meat; fish; eggs; milk
Nonagriculture	
Industry	Cocoa processing; fish processing; other food processing; mines; other manufacturing; electricity and water; construction
Services	Transportation services; trade; finance; government; community services
Regions	10 nationally defined regions
Households	20 aggregate households representing rural and urban in 10 regions
Data sources	Ghana Living Standards Survey 4, 1998/99 (GLSS4) (Ghana Statistical Service)
	Agriculture in Ghana, Facts and Figures (Ministry of Food and Agriculture 2003)
	FAOSTAT (for agriculture) and World Bank and IMF (for sector GDP and trade)
Rwanda	**Economywide multimarket model**
Agriculture	
Staple crops	Maize; rice; wheat; sorghum; cassava; potatoes; sweet potatoes; other root crops; beans; peas; bananas
Export crops	Coffee; tea
Other	Peanuts; soybeans; vegetable oil; vegetables; fruits; sugar; beverages; beef; mutton; poultry; other meat; fish; eggs; milk
Nonagriculture	
Industry	Home processing; industry
Services	Services
Regions	11 nationally defined provinces plus 1 capital city
Households	48 aggregate households representing rural and urban in 12 regions by gender of household heads
Data sources	Household Living Condition Survey, 1999–2001 (EICV)
	Agricultural Statistics, 1998–2002 (Ministry of Agriculture, Animal Resources and Forestry)
	FAOSTAT (for agriculture) and World Bank and IMF (for sector GDP and trade)

(continued)

Table A3—Continued

Uganda	**Computable general equilibrium model**
Agriculture	
Staple crops	Maize; sorghum; cassava; sweet potato; mattock; horticulture; other agricultural crops
Export crops	Coffee; cash crops
Other	Livestock; forestry; fishing
Nonagriculture	
Industry	Meat; coffee processing; milling; beverages and tobacco; textiles; other manufacturing; fertilizer; petroleum; energy; construction
Services	Trade services; transport services; private services; public services
Regions	6 IFPRI-defined development domains (see Pender et al. 2001)
Households	9 representative households: urban (poor and nonpoor households); and rural (across the 6 agroecological zones and 1 nonfarm household).
Data sources	Uganda National Household Survey, 1999 (UBOS) IFPRI Uganda Social Accounting Matrix, 1999 World Bank (for sector GDP, population and labor force trends) FAOSTAT (for trends in agricultural yields)
Zambia	**Computable general equilibrium model**
Agriculture	
Staple crops	Maize; millet and sorghum; groundnuts; wheat; horticulture; other crops
Export crops	Sugar; cotton; tobacco; coffee
Other	Livestock; fisheries; forestry
Nonagriculture	
Industry	Mining; food, beverages, and tobacco; textiles and garments; wood and paper; fertilizer and chemicals; other manufacturing; electricity and water; capital goods; construction
Services	Trade and transport; hotel and catering; community services; financial services; public services
Regions	9 nationally defined provinces
Households	73 representative households: by 9 provinces; rural (small, medium, large, and nonfarm households); and urban (low, medium, and high cost-of-living areas)
Data sources	Living Conditions Monitoring Survey, 1998 (Central Statistical Office) IFPRI Zambia Social Accounting Matrix, 2001 IMF (for population and labor force trends) and World Bank (for GDP trends) FAOSTAT (for trends in agricultural yields)

$$AA^q_{R,Z,i,t+1} = AA^q_{R,Z,i,t}(1 + g_{A_{R,Z,i}}), \qquad (4)$$

where $g_{A_{R,Z,i}}$ is the annual area expansion rate for crop i with technology q. Given that 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

$$S_{R,Z,I,T} = \sum_q Y^q_{R,Z,i,t} \cdot AS^q_{R,Z,i,t}. \qquad (5)$$

Supply Function for Noncrop Sectors (livestock and nonagriculture)

$$S^{LV}_{R,Z,i,t} = SA^{LV}_{R,Z,i,t} \prod_j P^{\beta^{LV}_{R,Z,j}}_{R,Z,j,t}. \qquad (6)$$

Trends in the livestock and nonagricultural supply function, $SA^{LV}_{R,Z,i}$, are represented by:

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

where $g_{S_{R,Z,i}}$ is the annual growth rate of livestock and nonagricultural productivity and varies by region or district and commodity, and g_Y, g_A, and g_S from equations 2, 4, and 7, respectively, 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.[16] 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 district level). The homogeneity of degree zero condition is imposed on the supply function such that, within each time period, there is no area allocation response if all prices change proportionally. The other constraint on crop area function is imposed to avoid a simultaneous expansion of all crop areas over a given time period.

Demand Functions

District level per capita demand is a function of prices and income:

$$Dpc_{R,Z,i,t} = \prod_j PC_{R,Z,j,t}^{\varepsilon_{R,Z,i,j}} GDPpc_{R,Z,t}^{\varepsilon^I_{R,Z,i}}, \quad (8)$$

where $Dpc_{R,Z,i}$ is per capita demand for commodity i in region R and district Z, and $PC_{R,Z,j}$ is the consumer price for j in region R and district $Z; j = 1,2, \ldots, J$ (including two aggregate nonagricultural goods); $GDPpc_{R,Z}$ is per capita income for region R and district 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 $\varepsilon^I_{R,Z,i}$ is income elasticity such that:

$$\sum_j^J \varepsilon_{R,Z,i,j} + \varepsilon^I_{R,Z,i} = 0, \text{ and}$$
$$\sum_j^J sh_{R,Z,j} + \varepsilon^I_{R,Z,i} = 1, \quad (9)$$

where $sh_{R,Z,i}$ is the expenditure share of commodity i. Income elasticity is estimated using Household Income, Consumption, and Expenditure Survey (HICES; CSA 2001) data for the rural and urban. Owing to the constraint of sample size, estimation at the subnational level is not significant, and hence we assume similar income elasticity for all the rural households and a similar one for all the urban households. The price elasticities are calculated from the above two constraint equations, with an assumption on the subsistence consumption level for each commodity in a linear expenditure demand system.

Relationship between Producer and Consumer Prices

It is assumed that import and export parity prices are the border prices adjusted by trade margins. In the case of the Ethiopian model, 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 district-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:

$$PC_{i,t} \leq (1 + Wm_i) \cdot PWM_i, \quad (10)$$

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 district level and national market prices (for consumer prices) is:

$$PC_{R,Z,i,t} = (1 + Dgap_{R,Z,i}) \cdot PC_{i,t}, \quad (11)$$

[16]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.

where $Dgap_{R,Z,i}$ is negative if Z is in the 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:

$$P_{i,t} \geq (1 - Wm_i) \cdot PWE_i, \tag{12}$$

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

$$PC_{R,Z,i,t} = (1 + Dm_{R,Z,i}) \cdot P_{R,Z,i,t}, \tag{13}$$

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

$$(1 - Wm_i) \cdot PWE_i \leq P_{i,t} \leq PC_{i,t} \leq (1 + Wm_i) \cdot PWM_i. \tag{14}$$

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

$$P_{i,t} = (1 - Wm_i) \cdot PWE_i, E_{i,t} > 0; \tag{15}$$

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

$$PC_{i,t} = (1 + Wm_i) \cdot PWM_i, M_{i,t} > 0; \tag{16}$$

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) owing to increased demand exceeding 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 districts 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):

$$DEF_{R,Z,i,t} = Dpc_{R,Z,i,t} \cdot PoP_{R,Z,t} - S_{R,Z,i,t}, \tag{17}$$

where PoP is population in region R, district Z, at time t.

Balance of Demand and Supply at the National Level

$$\sum_{R,Z} S_{R,Z,i,t} + M_{i,t} - E_{i,t} = \sum_{R,Z} Dpc_{R,Z,i,t} \cdot PoP_{R,Z}. \tag{18}$$

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 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:

$$GDP_{R,Z,t} = \sum_i P_{R,Z,j,t} \cdot S_{R,Z,j,t}, \tag{19}$$

Income per capita is:

$$GDPpc_{R,Z,t} = \frac{GDP_{R,Z,t}}{PoP_{R,Z,t}}. \quad (20)$$

Poverty Population and Poverty Rate

Let $PoorInc^{rur}$ be the (per capita) poverty line expenditure for rural areas and $GDP^{rur}_{R,Z,t}$ be total rural income in region R and district Z at time t; let $Sh^{rur}_{R,Z,h}$ be income share for rural household group h in region R and zone Z; the rural population of household group h, $Pop^{rur}_{R,Z,h,t}$, 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

$$I^{rur}_{R,Z,h,t} = Sh^{rur}_{R,Z,h} \cdot GDP^{rur}_{R,Z,t}; \quad \sum_h Sh^{rur}_{R,Z,h} = 1. \quad (21)$$

$I^{rur}_{R,Z,h,t}$ can be also defined as total expenditure and $I^{rur}_{R,Z,h,t} = \sum_{i=1}^{34} P_{R,Z,i,0} Dpc^{rur}_{R,Z,h,i,t}$. Per capita income in this household group is

$$Ipc^{rur}_{R,Z,h,t} = \frac{I^{rur}_{R,Z,h,t}}{Pop^{rur}_{R,Z,h,t}}, \quad (22)$$

if $Ipc^{rur}_{R,Z,h,t} < PoorInc^{rur}$ population $Pop^{rur}_{R,Z,h,t}$ is in the poor. (23)

Two factors affect $I^{rur}_{R,Z,h,t}$ in the simulations, $GDP^{rur}_{R,Z,t}$ and $Dpc^{rur}_{R,Z,h,i,t}$. $GDP^{rur}_{R,Z,t}$ is directly solved from the EMM model. Changes in $Dpc^{rur}_{R,Z,h,i,t}$ are assumed to be proportional to the same commodity consumed by the representative rural household in the same district. For example, in the case of the Ethiopian model, if consumption of teff increases by 1.3 percent at $t = 2006$ for the rural household in zone of West Tigray owing to an increase in $GDP^{rur}_{R,Z,t}$ for R = Tigray, Z = West Tigray, and $t = 2006$, then there is a 1.3 percent increase in the spending on teff in all 143 sample households in the rural West Tigray represented in the microsimulation model, that is, an increase in $Dpc^{rur}_{R,Z,h,i,t}$ for R = Tigray, Z = West Tigray, h = households represented by the rural West Tigray, i = teff, and $t = 2006$. However, the share of teff in each of the 143 households' total expenditure varies. Therefore, the 1.3 percent increase in teff expenditure will affect each of the 143 households differently, depending on the budget share of teff in their consumption basket; that is, $I^{rur}_{R,Z,h,t}$ varies by household in the simulations. The effect on total household expenditure $I^{rur}_{R,Z,h,t}$ will be larger for a household that spends more of its income on teff than for those that spend less income on teff. These differential effects occur for all commodities included in the EMM model. With such changes, a household whose total expenditure $Ipc^{rur}_{R,Z,h,0}$ is less than $PoorInc^{rur}$ initially can move out of poverty, if the total expenditure of its family members, $Ipc^{rur}_{R,Z,h,0}$, is greater than $PoorInc^{rur}$ at $t = 2006$.

The new poverty population in the rural area is the sum of $Pop^{rur}_{R,Z,h,t}$ over h for all h with $Ipc^{rur}_{R,Z,h,t} < PoorInc^{rur}$. 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 for the country as a whole.

Mathematical Specification of the CGE Models

A recursive dynamic CGE model can be separated into within-period and between-period components. The former describes a static single-period model in which consumers and producers behave myopically (that is, without factoring future expectations into their current decisionmaking). The dynamics of the model involve updating the parameters of the subsequent period to reflect either changes that have taken place in the current period, such as investment spending, or exogenous changes in the economic environment, such as population growth. The mathematical specification of the core static model is presented first, followed by the dynamics of the model. All variables and equations are shown in Tables A4 and A5 near the end of this section of the appendix. The mathematical equations forming the static model are grouped into sections. Initially the production and price structure of the model is described, which includes the determination of import and export demand [equations (24) to (50) in Table A5]. Having generated incomes for the factors of production, the description shifts to determining the level of institutional incomes and consumption, as well as the remaining components of demand [equations (51) to (60)]. The third section of equations describes the equilibrium conditions imposed on the model [equations (61) to (66)]. The remaining equations (67 to 72) govern the accumulation of capital, which is the endogenous component of the dynamic model.

Production is characterized by a two-level nesting structure and involves the combining of factors and intermediate inputs. Aggregate intermediate quantity and price are determined by a Leontief or fixed share aggregation of individual intermediate commodities. This is shown in equations (24) and (25), in which the aggregate quantity of intermediates for an activity $QINTA_a$ is comprised of the fixed shares of the individual intermediate commodities used in that activity's production $QINT_{ca}$. The use of fixed coefficients ica_{ca} (as opposed to allowing substitution between intermediates) follows from the assumption that the intermediate demands of a particular activity are predetermined by technology. Since intermediate commodities are purchased in the market, the aggregate price of the intermediate inputs $PINTA_a$ for an activity is equal to the market price of each intermediate commodity PQ_c multiplied by its share ica_{ca} in total intermediate use. With the exception of nontraded goods, each intermediate commodity comes from domestic and foreign sources and is therefore treated as a composite input. Firms are able to substitute between domestic and foreign intermediate inputs through the constant elasticity of substitution (CES) function given by equation (44).

Unlike the Leontief treatment of intermediates, factors are combined into a composite primary factor under a CES function [equations (26) and (27)], which combines the factor demands of an activity QF_{fa} into an aggregate quantity of value-added inputs for that activity QVA_a. This treatment allows for substitution between factors when determining composite factor inputs. Interfactor substitutability increases when the value of ρ_a^{va} (which is a transformation of the elasticity of factor substitution) is reduced. An activity's factor demand is driven by cost minimization based on the relative prices of factors, such that their marginal revenue product equals their marginal cost. The marginal cost of the composite factor at the top of the factor demand nest for each sector is equal to its marginal revenue product, where marginal cost is the economy-wide average wage W_f multiplied by a sector-specific distortion term $WFDIST_{fa}$. Total factor productivity (TFP) is reflected by α_a^{va} and factor-specific productivity by α_{fa}^{vaf}.

Demand for individual factors at lower levels of the nested demand system is given in equations (28) and (29), in which the latter is the first-order condition. In these equations f' and f'' are the lower-level factors. Demand for an individual factor f' in a given level of the nested structure is driven by cost minimization based on the relative prices of all factors f'' both at the same level and with substitution possibilities with f'. Substitution possibilities are determined by ρ_{fa}^{van}, which is a transformation of the elasticity of factor substitution.

The composite factor quantities and aggregate intermediate quantities are combined under a Leontief specification [equations (30) and (31)] to arrive at a final level of output for each activity QA_a. This production function is strongly separable, since the

Table A4 CGE model sets, parameters, and variables

Symbol	Explanation	Symbol	Explanation
Sets			
$a \in A$	Activities	$c \in CEN(\subset C)$	Commodities not in *CE*
$a \in ALEO(\subset A)$	Activities with a Leontief function at the top of the technology nest	$c \in CMN(\subset C)$	Commodities not in *CM*
$c \in C$	Commodities	$c \in CT(\subset C)$	Transaction service commodities
$c \in CD(\subset C)$	Commodities with domestic sales of domestic output	$c \in CX(\subset C)$	Commodities with domestic production
$c \in CDN(\subset C)$	Commodities not in *CD*	$f \in F$	Factors
$c \in CE(\subset C)$	Exported commodities	$i \in INS$	Institutions (domestic and rest of world)
		$i \in INSD(\subset INS)$	Domestic institutions
		$i \in INSDNG(\subset INSD)$	Domestic nongovernment institutions
Parameters			
$cwts_c$	Weight of commodity *c* in the CPI	pwe_c	Export price (foreign currency)
$dwts_c$	Weight of commodity *c* in the producer price index	pwm_c	Import price (foreign currency)
ica_{ca}	Quantity of *c* as intermediate input per unit of activity *a*	$qdst_c$	Quantity of stock change
$icd_{cc'}$	Quantity of commodity *c* as trade input per unit of *c′* produced and sold domestically	$\overline{qg}_c$	Base-year quantity of government demand
$ice_{cc'}$	Quantity of commodity *c* as trade input per exported unit of *c′*	$\overline{qinv}_c$	Base-year quantity of private investment demand
$icm_{cc'}$	Quantity of commodity *c* as trade input per imported unit of *c′*	$shif_{if}$	Share for domestic institution *i* in income of factor *f*
$inta_a$	Quantity of aggregate intermediate input per activity unit	$shii_{ii'}$	Share of net income of *i′* to *i* ($i' \in INSDNG'$; $i \in INSDNG$)
iva_a	Quantity of aggregate intermediate input per activity unit	ta_a	Tax rate for activity *a*
$\overline{mps}_i$	Base savings rate for domestic institution *i*	$\overline{tins}_i$	Exogenous direct tax rate for domestic institution *i*
$mps01_i$	0–1 parameter with 1 for institutions with potentially flexed direct tax rates	$tins01_i$	0–1 parameter with 1 for institutions with potentially flexed direct tax rates
		tm_c	Import tariff rate
		tq_c	Rate of sales tax
		$trnsfr_{if}$	Transfer from factor *f* to institution *i*
Greek Symbols			
α_a^a	Efficiency parameter in the CES activity function	δ_c^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 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	CET function shift parameter	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 domestic commodity aggregation function	ρ_c^t	CET function exponent
δ_c^q	Armington function share parameter	η_{fat}^a	Sector share of new capital
		υ_f	Capital depreciation rate
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 supplied of factor
$\overline{FSAV}$	Foreign savings (FCU)	$\overline{TINSADJ}$	Direct tax scaling factor (= 0 for base; exogenous variable)
$\overline{GADJ}$	Government consumption adjustment factor	$\overline{WFDIST}_{fa}$	Wage distortion factor for factor *f* in activity *a*
$\overline{IADJ}$	Investment adjustment factor		

(continued)

Table A4—Continued

Symbol	Explanation	Symbol	Explanation
Endogenous variables			
AWF^a_{ft}	Average capital rental rate in time period t	QHA_{ach}	Quantity of household home consumption of commodity c from activity a for household h
$DMPS$	Change in domestic institution savings rates (= 0 for base; exogenous variable)		
DPI	Producer price index for domestically marketed output	$QINTA_a$	Quantity of aggregate intermediate input
EG	Government expenditures	$QINT_{ca}$	Quantity of commodity c as intermediate input to activity a
EH_h	Consumption spending for household	$QINV_c$	Quantity of investment demand for commodity
EXR	Exchange rate (LCU per unit of FCU)		
$GSAV$	Government savings	QM_c	Quantity of imports of commodity c
MPS_i	Marginal propensity to save for domestic non-government institution (exogenous variable)	QQ_c	Quantity of goods supplied to domestic market (composite supply)
PA_a	Activity price (unit gross revenue)	QT_c	Quantity of commodity demanded as trade input
PDD_c	Demand price for commodity produced and sold domestically		
		QVA_a	Quantity of (aggregate) value added
PDS_c	Supply price for commodity produced and sold domestically	QX_c	Aggregated quantity of domestic output of commodity
PE_c	Export price (domestic currency)	$QXAC_{ac}$	Quantity of output of commodity c from activity a
$PINTA_a$	Aggregate intermediate input price for activity a		
PK_{ft}	Unit price of capital in time period t	RWF_f	Real average factor price
PM_c	Import price (domestic currency)	$TABS$	Total nominal absorption
PQ_c	Composite commodity price	$TINS_i$	Direct tax rate for institution i ($i \in$ INSDNG)
PVA_a	Value-added price (factor income per unit of activity)		
		$TRII_{ii'}$	Transfers from institution i' to i (both in the set INSDNG)
PX_c	Aggregate producer price for commodity		
$PXAC_{ac}$	Producer price of commodity c for activity a	WF_f	Average price of factor
QA_a	Quantity (level) of activity	YF_f	Income of factor f
QD_c	Quantity sold domestically of domestic output	YG	Government revenue
QE_c	Quantity of exports	YI_i	Income of domestic nongovernment institution
QF_{fa}	Quantity demanded of factor f from activity a		
QG_c	Government consumption demand for commodity	YIF_{if}	Income to domestic institution i from factor f
QH_{ch}	Quantity consumed of commodity c by household h	K^a_{fat}	Quantity of new capital by activity a for time period t

composite primary factor cannot be substituted for the aggregate intermediate; nor can intermediates of one sector be substituted for intermediates of another. This additive separability can be seen in equation (32), in which the aggregate price of one unit of output from each activity PA_a is calculated as the weighted sum of factor and intermediate prices exclusive of producer taxes ta_a.

Because each activity can produce more than a single commodity, equations (33) and (34) convert each activity's output and price into a commodity output $QXAC_{ac}$ and price $PXAC_{ac}$ based on fixed shares θ_{ac}. Conversely, since each commodity can be produced by more than one activity, it is necessary to combine these commodities from their various sources. Although it is assumed that an activity's production of commodities is fixed by technology, it is assumed that demanders of a commodity are relatively indifferent to which activity produced the final commodity. As such, the aggregation of commodities across activities is governed by imperfect substitution or a CES function. Equations (35) and (36) show the CES aggregation function and its first-order conditions. In these equations output from each activity $QXAC_{ac}$ is combined across activities to form a composite

Table A5 CGE model equations

Production and price equations

$$QINT_{ca} = ica_{ca} \cdot QINTA_{a} \tag{24}$$

$$PINTA_{a} = \sum_{c \in C} PQ_{c} \cdot ica_{ca} \tag{25}$$

$$QVA_{a} = \alpha_{a}^{va} \cdot \left(\sum_{f \in F} \delta_{fa}^{va} \cdot (\alpha_{fa}^{vaf} \cdot QF_{fa})^{-\rho_{a}^{va}} \right)^{-\frac{1}{\rho_{a}^{va}}} \tag{26}$$

$$W_{f} \cdot \overline{WFDIST}_{fa} = PVA_{a} \cdot (1 - tva_{a}) \cdot QVA_{a} \cdot \left(\sum_{f \in F'} \delta_{fa}^{va} \cdot (\alpha_{fa}^{vaf} \cdot QF_{fa})^{-\rho_{a}^{va}} \right)^{-1} \cdot \delta_{fa}^{va} \cdot (\alpha_{fa}^{vaf} \cdot QF_{fa})^{-\rho_{a}^{va}-1} \tag{27}$$

$$QF_{fa} = \alpha_{fa}^{van} \cdot \left(\sum_{f' \in F} \delta_{ff'\alpha}^{van} \cdot QF_{f'a}{}^{-\rho_{fa}^{van}} \right)^{-\frac{1}{\rho_{fa}^{van}}} \tag{28}$$

$$W_{f'} \cdot WFDIST_{f'a} = W_{f} \cdot WFDIST_{fa} \cdot QF_{fa} \cdot \left(\sum_{f'' \in F} \delta_{ff''\alpha}^{van} \cdot QF_{f''a}{}^{-\rho_{fa}^{van}} \right)^{-1} \cdot \delta_{ff'\alpha}^{van} \cdot (\alpha_{fa}^{vaf} \cdot QF_{f'a}{}^{-\rho_{fa}^{van}-1} \tag{29}$$

$$QVA_{a} = iva_{a} \cdot QA_{a} \tag{30}$$

$$QINTA_{a} = inta_{a} \cdot QA_{a} \tag{31}$$

$$PA_{a} \cdot (1 - ta_{a}) \cdot QA_{a} = PVA_{a} \cdot QVA_{a} + PINTA_{a} \cdot QINTA_{a} \tag{32}$$

$$QXAC_{ac} = \theta_{ac} \cdot QA_{a} \tag{33}$$

$$PA_{a} = \sum_{c \in C} PXAC_{ac} \cdot \theta_{ac} \tag{34}$$

$$QX_{c} = \alpha_{c}^{ac} \cdot \left(\sum_{a \in A} \delta_{ac}^{ac} \cdot QXAC_{ac}{}^{-\rho_{c}^{ac}} \right)^{-\frac{1}{\rho_{c}^{ac}-1}} \tag{35}$$

$$PXAC_{ac} = PX_{c} \cdot QX_{c} \left(\sum_{a \in A'} \delta_{ac}^{ac} \cdot QXAC_{ac}{}^{-\rho_{c}^{ac}} \right)^{-1} \cdot \delta_{ac}^{ac} \cdot QXAC_{ac}{}^{-\rho_{c}^{ac}-1} \tag{36}$$

$$PE_{c} = pwe_{c} \cdot EXR - \sum_{c' \in CT} PQ_{c} \cdot ice_{c'c} \tag{37}$$

$$QX_{c} = \alpha_{c}^{t} \cdot (\delta_{c}^{t} \cdot QE_{c}^{\rho_{c}^{t}} + (1 - \delta_{c}^{t}) \cdot QD_{c}^{\rho_{c}^{t}})^{\frac{1}{\rho_{c}^{t}}} \tag{38}$$

$$\frac{QE_{c}}{QD_{c}} = \left(\frac{PE_{c}}{PDS_{c}} \cdot \frac{1 - \delta_{c}^{t}}{\delta_{c}^{t}} \right)^{\frac{1}{\rho_{c}^{t}-1}} \tag{39}$$

$$QX_{c} = QD_{c} + QE_{c} \tag{40}$$

$$PX_{c} \cdot QX_{c} = PDS_{c} \cdot QD_{c} + PE_{c} \cdot QE_{c} \tag{41}$$

$$PDD_{c} = PDS_{c} + \sum_{c' \in CT} \mathrm{PQ}_{\mathrm{c}'} \cdot icd_{c'c} \tag{42}$$

$$PM_{c} = pwm_{c} \cdot (1 + tm_{c}) \cdot EXR + \sum_{c' \in CT} PQ_{c'} \cdot icm_{c'c} \tag{43}$$

$$QQ_{c} = \alpha_{c}^{q} \cdot (\delta_{c}^{q} \cdot QM_{c}^{-\rho_{c}^{q}} + (1 - \delta_{c}^{q}) \cdot QD_{c}^{-\rho_{c}^{q}})^{-\frac{1}{\rho_{c}^{q}}} \tag{44}$$

$$\frac{QM_{c}}{QD_{c}} = \left(\frac{PDD_{c}}{PM_{c}} \cdot \frac{\delta_{c}^{q}}{1 - \delta_{c}^{q}} \right)^{\frac{1}{1+\rho_{c}^{q}}} \tag{45}$$

$$QQ_{c} = QD_{c} + QM_{c} \tag{46}$$

$$PQ_{c} \cdot (1 - tq_{c}) \cdot QQ_{c} = PDD_{c} \cdot QD_{c} + PM_{c} \cdot QM_{c} \tag{47}$$

$$QT_{c} = \sum_{c' \in C'} (icm_{cc'} \cdot QM_{c'} + ice_{cc'} \cdot QE_{c'} + icd_{cc'} \cdot QD_{c'}) \tag{48}$$

$$\overline{CPI} = \sum_{c \in C} PQ_{c} \cdot cwts_{c} \tag{49}$$

$$DPI = \sum_{c \in C} PDS_{c} \cdot dwts_{c} \tag{50}$$

(continued)

Table A5—Continued

Institutional incomes and domestic demand equations

$$YF_f = \sum_{a \in A} WF_f \cdot \overline{WFDIST}_{fa} \cdot QF_{fa} \quad (51)$$

$$YIF_{if} = shif_{if} \cdot [YF_f - trnsfr_{row\,f} \cdot EXR] \quad (52)$$

$$YI_i = \sum_{f \in F} YIF_{if} + \sum_{i' \in INSDNG'} TRII_{ii'} + trnsfr_{i\,gov} \cdot \overline{CPI} + trnsfr_{i\,row} \cdot EXR \quad (53)$$

$$TRII_{ii'} = shii_{ii'} \cdot (1 - MPS_{i'}) \cdot (1 - \overline{tins}_{i'}) \cdot YI_{i'} \quad (54)$$

$$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{ih}\right) \cdot (1 - MPS_h) \cdot (1 - \overline{tins}_h) \cdot YI_h \quad (55)$$

$$PQ_c \cdot QH_{ch} = PQ_c \cdot \gamma^m_{ch} + \beta^m_{ch} \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma^m_{c'h}\right) \quad (56)$$

$$QINV_c = IADJ \cdot \overline{qinv}_c \quad (57)$$

$$QG_c = \overline{GADJ} \cdot qg_c \quad (58)$$

$$EG = \sum_{c \in C} PQ_c \cdot QG_c + \sum_{i \in INSDNG} trnsfr_{i\,gov} \cdot \overline{CPI} \quad (59)$$

$$YG = \sum_{i \in INSDNG} \overline{tins}_i \cdot YI_i + \sum_{a \in A} ta_a \cdot PA_a \cdot QA_a + \sum_{c \in CMNR} tm_c \cdot pwm_c \cdot QM_c \cdot EXR$$
$$+ \sum_{c \in C} tq_c \cdot PQ_c \cdot QQ_c + \sum_{f \in F} YF_{gov\,f} + trnsfr_{gov\,row} \cdot EXR \quad (60)$$

System constraints and macroeconomic closures

$$QQ_c = \sum_{a \in A} QINT_{ca} + \sum_{h \in H} QG_{ch} + QG_c + QINV_c + qdst_c + QT_c \quad (61)$$

$$\sum_{a \in A} QF_{fa} = QFS_f \quad (62)$$

$$YG = EG + GSAV \quad (63)$$

$$\sum_{c \in CMNR} pwm_c \cdot QM_c + \sum_{f \in F} trnsfr_{row\,f} = \sum_{c \in CMNR} pwe_c \cdot QE_c + \sum_{i \in INSD} trnsfr_{i\,row} + FSAV \quad (64)$$

$$\sum_{i \in INSDNG} MPS_i \cdot (1 - \overline{tins}_i) \cdot YI_i + GSAV + EXR \cdot FSAV = \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c \quad (65)$$

$$MPS_i = \overline{mps}_i \cdot (1 + MPSADJ) \quad (66)$$

Capital accumulation and allocation equations

$$AWF^a_{ft} = \sum_a \left[\left(\frac{QF_{fat}}{\sum_{a'} QF_{fa't}}\right) \cdot WF_{ft} \cdot WFDIST_{fat}\right] \quad (67)$$

$$\eta^a_{fat} = \left(\frac{QF_{fat}}{\sum_{a'} QF_{fa't}}\right) \cdot \left(\beta^a \cdot \left(\frac{WF_{fat} \cdot WFDIST_{fat}}{AWF^a_{ft}} - 1\right) + 1\right) \quad (68)$$

$$\Delta K^a_{fat} = \eta^a_{fat} \cdot \left(\frac{\sum_c PQ_{ct} \cdot QINV_{ct}}{PK_{ft}}\right) \quad (69)$$

$$PK_{ft} = \sum_c PQ_{ct} \cdot \frac{QINV_{ct}}{\sum_{c'} QINV_{c't}} \quad (70)$$

$$QF_{fat+1} = QF_{fat} \cdot \left(1 + \frac{\Delta K^a_{fat}}{QF_{fat}} - \upsilon_f\right) \quad (71)$$

$$QFS_{ft+1} = QFS_{ft} \cdot \left(1 + \frac{\sum_a \Delta K_{fat}}{QFS_{ft}} - \upsilon_f\right) \quad (72)$$

commodity output QX_c. Similarly the composite output's price PX_c is the aggregation of each activity's commodity price $PXAC_{ac}$.

The output of each commodity is then distributed across domestic and foreign markets. Under the small-country assumption, the price of an exported commodity, shown in equation (37), is equal to the commodity's world export price pwe_c multiplied by the exchange rate EXR. Furthermore, since the export price represents the amount received by producers per unit sold abroad, the transaction costs per unit of output are removed from this price. This is equal to the share of transaction costs per commodity unit ice_c times the market price at which these transaction commodities are sold PQ_c.

For commodities that are sold both domestically and abroad, equations (38) and (39) represent the constant elasticity of transformation (CET) function determining the quantity and price of exported and domestically sold commodities. These equations represent the ease with which producers are able to substitute production between the two markets. Domestic and foreign commodities become more homogeneous as the elasticity of transformation increases toward infinity. This imperfect substitution reflects the view that a producer can shift small amounts of resources between production for the domestic and foreign markets without any loss of productive efficiency. Larger shifts in production toward a different market, however, will require the use of factors that are less efficient. Thus the CET is concave and the final allocation of a given output is determined by the relative domestic and export prices.

Some commodities are produced solely for the domestic or foreign market. Equation (40) allocates production QX_c to one of these markets. In such cases either the quantity of goods supplied to the domestic market QD_c or the quantity exported QE_c is zero. In equation (41), the value of output $PX_c \cdot QX_c$ must be equal to either the value of exports $PE_c \cdot QE_c$ or the value of domestic sales $PDS_c \cdot QD_c$, where PDS_c is the domestic supply price. In equation (42) the domestic supply price of a commodity PDS_c is converted into the demand price of a domestically produced commodity PDD_c by incorporating domestic marketing and trade margins. These are calculated by multiplying a commodity's transactions cost share $icd_{c'c}$ by the market price at which the transactions commodities are sold at $PQ_{c'}$.

The demand for a commodity can either be satisfied by domestic or foreign supply. The price of an imported commodity PM_c, shown in equation (43), is equal to the commodity's world import price pwm_c multiplied by the exchange rate EXR and any import tariffs tm_c. Any additional transactions costs are added, and are equal to the share of these costs per commodity unit icm_c multiplied by the market price of these transaction commodities PQ_c.

For those commodities that have both domestic and foreign supply, equations (44) and (45) represent the CES or Armington function determining the final quantity and price of imported QM_c and domestically supplied QD_c commodities. These two commodities are combined to form a composite commodity QQ_c that is then supplied to the market. The elasticity of substitution, which is a transformation of ρ_c^q, represents the ease at which consumers are willing to shift demand between domestic and foreign products. Equation (46) applies only to those commodities that are solely imported or domestically supplied. This replaces the Armington function and ensures that composite supply QQ_c is equal to either domestic QD_c or foreign supply QM_c.

Equation (47) is the total value of absorption, or alternatively, the total spending on a commodity at demander prices. The value of absorption is composed of the final composite commodity's price exclusive of sales taxes $PQ_c \cdot (1 - tq_c)$ multiplied by the quantity of the composite QQ_c. Except for those commodities that are solely exported, this value of absorption is equal to the sum of the value of domestic $PDD_c \cdot QD_c$ and foreign supply $PM_c \cdot QM_c$. The composite commodity is supplied to the domestic market and is purchased at market prices PQ_c to satisfy intermediate $QINT_{c,a}$, household $QH_{c,h}$, government QG_c, and investment $QINV_c$ demand.

Transaction services have an additional component of demand generated through indirect demand for trade inputs during the import, export, and domestic sale of commodities (Equation 48). A fixed quantity of trade inputs are used per unit of the commodity being traded. These are shown in the equation as $icm_{cc'}$ for imports, $ice_{cc'}$ for exports, and $icd_{cc'}$ for domestically supplied commodities. These shares are multiplied by the quantity of the traded commodity in order to arrive at the total additional demand for transaction services QT_c.

The final two production and price equations (49 and 50) calculate consumer and domestic price indices. The consumer price index CPI is equal to the weighted sum of the market price of each commodity PQ_c, where the weight $cwts_c$ is the share of each commodity in the household consumption basket. Similarly, the domestic price index DPI is the domestic supply price PDS_c weighted by the share of each commodity in total domestic supply $dwts_c$. The consumer price index is used as the numéraire in the model, and the domestic price index is used to derive the real exchange rate. The model is homogeneous of degree zero in prices, since a doubling of the numéraire will leave relative prices, and hence the real allocation of resources, unchanged.

The equations have so far defined the production and price structure of the model. The next block of equations determines the generation of institutional incomes and how this in turn generates demand for commodities. The model distinguishes between a number of institutions including enterprises, households, and the government. Factor employment in the production process generates factor incomes as shown in equation (51). Total income for each factor, YF_f, is equal to its economywide wage WF_f multiplied by both the quantity employed QF_{fa} in each activity and its sector-specific wage-distortion term $WFDIST_{fa}$. Factor incomes are then transferred to either domestic institutions or to the rest of the world. Equation (52) shows how foreign factor remittances measured in domestic prices $trnsfr_{row\,f} \cdot EXR$ are removed from factor incomes, before the remaining income is distributed across domestic institutions based on fixed shares $shif_{if}$ to arrive at a total value of factor income for each institution YIF_{if}.

Direct payments from factors YIF_{if} only form part of the total income YI_i earned by domestic nongovernment institutions. As shown in equation (53), other income sources include transfers received from other institutions $TRII_{ii'}$, CPI-indexed transfers from the government $trnsfr_{i\,gov} \cdot \overline{CPI}$, and domestically valued transfers from the rest of the world $trnsfr_{i\,row} \cdot EXR$. Domestic nongovernment institutions make transfers to other institutions ($TRII_{ii'}$) in equation (54). For example, households make transfers to each other, and enterprises transfer dividend income (or indirect capital income) to households. The value of these transfers is a fixed share $shii_{ii'}$ of the institution's income $YI_{i'}$ after paying taxes $\overline{tins}_{i'}$ and saving $MPS_{i'}$.

Having determined households' income, equation (55) calculates the amount of income available for consumption spending, EH_h. This amount is equal to total household income less payments for direct taxes $tins_h$, savings MPS_h, and the share of income transferred to other institutions $shii_{ih}$. Households maximize a Stone–Geary utility function subject to a budget constraint. The resulting first-order condition is referred to as a linear expenditure system (LES) since spending on individual commodities QH_{ch} is a linear function of total spending EH_h. Total household expenditure is distributed across commodities in equation (56). A portion of consumption for each commodity, $PQ_c \cdot \gamma^m_{ch}$, is treated as independent of the level of disposable income available for consumption spending. The remaining income is then distributed among commodities according to fixed shares, β^m_{ch}. Household utility is weakly separable since domestic and foreign commodities are imperfectly substitutable. Together with the linear homogeneity of the LES demand system, this implies that the consumers' decisions can be decomposed into "two-stage budgeting." At the first stage, consumers maximize the Stone–Geary utility function of composite commodities subject to a given level of income and composite prices. At the second stage, consumers maximize the subutility functions subject to the expenditure allocated to each commodity in the first decision stage.

Fixed investment demand $QINV_c$ across commodities is defined in equation (57) as the base-year quantity $qinv_c$ multiplied by an adjustment factor *IADJ*. By using an adjustment factor, which has a value of one in the base, the assumption is that the commodity composition of the investment bundle remains unchanged as the level of investment adjusts. Another component of final demand is government consumption spending [equation (58)]. This quantity is treated in the same way as investment demand. Base-year government spending on commodities qg_c is multiplied by an adjustment factor *GADJ* to arrive at a final level of spending on each commodity QG_c. The total value of total government spending *EG* is equal to the market value of government consumption spending $PQ_c \cdot QC_c$, as well as CPI-indexed transfers to other institutions $trnsfr_{i\,gov} \cdot \overline{CPI}$ [Equation (59)]. Government expenditure is financed by government revenue *YG*. As shown in equation (60), income sources include direct taxes $tins_i$, activity taxes ta_a, import tariffs tm_c and tmr_{cr}, sales taxes tq_c, factor income $YF_{gov\,f}$, and transfers received from the rest of the world $trnsfr_{gov\,row}$. Depending on changes in government spending, changes in revenues and the deficit can therefore affect the level of investment or savings in the economy by influencing the availability of loanable funds. The extent to which this is possible depends on the adjustment mechanisms in the economy.

The third block of equations describes system constraints and model closures. These equilibrium constraints embody assumptions or "closure rules" determining how the macro-economy and commodity and factor markets work. Equilibrium exists in the commodity market if total demand equals total supply for each commodity. Equation (61) shows how total supply for the composite commodity QQ_c has to equal the sum of intermediate demand $QINT_{c\,a}$, household consumption $QH_{c\,h}$, government consumption QG_c, investment demand $QINV_c$, changes in inventories $qdst_c$, and the indirect demand for transactions services QT_c. Inventory demand is treated as exogenous in the model and remains fixed at base-year values. Factor market equilibrium, as shown in equation (62), implies that the sum of factor demands across all activities $QF_{f\,a}$ must equal the total supply of that factor QFS_f. Three closures are possible for each factor in the model: (1) factors are mobile across sectors but total supply is fixed; (2) factor supply is fixed and factors are immobile across sectors; or (3) factor supply is perfectly elastic at a fixed real wage. In the Ugandan and Zambian models land and labor is assumed to be fully employed and mobile across sectors. This allows for HIV/AIDS and rapid population growth to be incorporated, which are important for Zambia and Uganda respectively. Capital supply is determined dynamically (described later) but is immobile across sectors within a given time period, thus reflecting short-run constraints.

Macroeconomic closures affect the government balance, the current account balance, and the workings of savings and investment in the economy. The government balance is shown in equation (63). Here total government income *YG* is equal to total government spending *EG* and government savings *GSAV*. If the government budget is in deficit, then the value of government savings is negative (that is, the government is borrowing or dis-saving). Three variables embodied in the government account are relevant to its macroeconomic closure. These include government savings *GSAV*, the level of government spending [*GADJ* from equation (58)], and the level of government income from the direct taxation of domestic institutions [$TINS_i$ from equations (54) and (55)]. One of these three variables must be held constant for equation (63) to be defined. In the Ugandan and Zambian models the direct tax rates imposed on domestic nongovernment institutions are held fixed thus assuming that the government is constrained in raising taxes to cover additional public spending.

The current account balance is defined in equation (64). The outflow of foreign currency is shown on the left hand side as the sum of import spending $pwm_c \cdot QM_c$ and transfers paid to the rest of the world $trnsfr_{row\,f}$, both of which are measured in foreign currency. In equilibrium, this outflow must be matched by an inflow of currency. Total inflows include earnings from exports $pwe_c \cdot QE_c$, transfers received from the rest of the world $trnsfr_{i\,row}$, and total foreign savings or borrowing $FSAV$. For current account equilibrium to be defined either the level of foreign borrowing $FSAV$ or the exchange rate EXR must be held fixed. In the Ugandan and Zambian models, the level of foreign savings is fixed, thus assuming that the country cannot borrow to finance additional spending.

The final macroeconomic account reflects the balance between savings and investment. In equation (65), total savings is the sum of private savings from post-tax disposable income $MPS_i \cdot (1 - TINS_i) \cdot YI_i$, government savings $GSAV$, and foreign savings $EXR \cdot FSAV$. In equilibrium this must equal the combined value of fixed investment $PQ_c \cdot QINV_c$ and inventory investment $PQ_c \cdot qdst_c$. Macroeconomic closure of this account implies that either investment is savings-driven (with MPS_i fixed), or savings is investment-driven (with $IADJ$ fixed). In the Ugandan and Zambian models, a savings-driven investment closure is adopted in which investment adjusts endogenously to the availability of loanable funds. Equation (66) shows how the saving rates of domestic nongovernment institutions MPS_i are comprised of the base-year rate mps_i multiplied by a scaling factor $MPSADJ$.

The description so far has outlined a static version of the CGE model, while the remainder of this section describes the dynamic extension of the model. A number of exogenous and endogenous changes take place over time and are important for capturing the growth process. Together these changes form a projected or counterfactual growth path for the economy. These interperiod adjustments include population and labor force growth, capital accumulation, factor productivity changes, and changes in foreign capital inflows and government expenditure.

Population growth is assumed to enter the model through its direct and positive affect on the level of private consumption spending. As shown in equation (56), each representative household consumes commodities under a linear expenditure system (LES) of demand. This system allows for an income-independent level of consumption $PQ_c \cdot \gamma^m_{ch}$ measured as the market value of each household's consumption of each commodity that is unaffected by changes in disposable income. The remaining terms in equation (56) determine the level of additional consumption demand that adjusts with changes in income. During the dynamic updating process and as the population grows, the level of each household's consumption of a particular commodity is adjusted upward to account for greater consumption demand. This adjustment is achieved by increasing the quantity of income-independent demand γ^m_{ch} at the rate of population growth.

The method of updating the relevant parameters to reflect changes in land and labor supply in the current model depends on the factor market closure chosen. Since land and labor supply is fixed under full employment, total land and labor supply [QFS_f in equation (62)] are adjusted upward each year in the Ugandan and Zambian models to reflect exogenously determined estimates of land and labor force growth. This specification allows for the effects of HIV/AIDS and other exogenous demographic factors to be taken into account, which the model would otherwise be unable to capture.

Unlike labor supply, all changes in total capital supply are endogenous in the dynamic model. In a given time period the total available capital is determined by the previous period's capital stock and investment spending. However, what remains to be decided is how the new capital stock resulting from previous investment is to be allocated across sectors. An extreme specification of the model would allocate investment in proportion to each sector's share in aggregate capital income or profits. However, in the current dynamic model, these proportions are adjusted by the ratio of each sector's profit rate to the average profit rate for the economy as a whole. Sectors with a higher-than-average profit rate receive a larger share of investment than their share in aggregate profits. This updating process involves four steps.

Equation (67) describes the first step at which the average economywide rental rate of capital AWF_{ft}^{a} is calculated for time period *t*. This rate is equal to the sum of the rental rates of each sector weighted by the sector's share of total capital factor demand. In the second step, each sector's share of the new capital investment η_{fat}^{a} is calculated by comparing its rental rate to the economywide average. For those sectors with above average rental rates, the second term on the right-hand side of equation (68) will be greater than one. The converse would be true for sectors with rental rates that are below average. This term is then multiplied by the existing share of capital stock to arrive at a sectoral distribution for new capital. The intersectoral mobility of investment is indicated by β^{a}. In the extreme case where β^{a} is zero there is no intersectoral mobility of investment funds, and all investment can be thought of as being funded by retained profits. Equation (69) shows the third step of the updating procedure in which the quantity of new capital is calculated as the value of gross fixed capital formation divided by the price of capital PK_{ft}. This quantity is then multiplied by each sector's share of new capital η_{fat}^{a} to arrive at a final quantity allocated to each sector (ΔK_{fat}^{a}). The determination of the unit capital price is shown in equation (70). In the final step the new aggregate quantity of capital QFS_{ft+1} and the sectoral quantities of capital QF_{fat+1} are adjusted from their previous levels to include new additions to the capital stock. In addition to these changes, there is also a loss of capital to account for depreciation (υ_{f}).

Along with changes in factor supply, the dynamic model also considers changes in factor productivity. This is done by multiplying either the α_{a}^{va} parameter in equation (27) by the percentage change in total factor productivity (TFP), or δ_{fa}^{va} in the case of factor-specific productivity. Finally, government consumption spending and transfers to households, as well as foreign transfers, are fixed in real terms within a particular period. It is necessary to exogenously increase these payments between periods. This is done by increasing the value of qg_{c} in equation (58) for government consumption spending, $trnsfr_{i\,gov}$ in equation (59) for government transfers to households, and $trnsfr_{i\,row}$ in equation (64) for foreign transfers.

Finally, the model is linked to a household expenditure survey by taking endogenous changes in commodity consumption from each aggregate household and adjusting the level of expenditure for the corresponding disaggregated households in the survey. As the data used to calibrate the model (that is, social accounting matrix) are constructed using the survey data, there is a direct mapping between commodities and households in the model and survey. Therefore changes in QH_{ch} from equation (56) (measured in base year prices) are used to update household expenditure in the survey. Standard poverty measures (including the poverty–growth elasticity) are then recalculated using the updated expenditure estimates and the unchanged poverty line.

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