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DSGD Discussion Paper No. 29

The Role of Agriculture in Development: Implications for Sub-Saharan Africa

Xinshen Diao, Peter Hazell, Danielle Resnick, and James Thurlow

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ABSTRACT

This paper 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 paper synthesizes both the traditional theoretical literature on agriculture's role in the development process and discusses more recent literature that remains skeptical about agriculture's development potential for Africa. In order to examine in greater detail the relevance for Africa of both the "old" and "new" literatures on agriculture, the paper provides a typology of African countries based on their stage of development, agricultural conditions, natural resources, and geographic location. This typology shows that agriculture's growth and poverty-reduction potential 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) using economy-wide, macro-micro linkage models.

The paper shows that despite recent skepticism, agricultural growth is still important for most low-income African countries. The country level analyses emphasize that agriculture is especially important for poverty reduction. In particular, broad-based agricultural growth in the staple food sectors reduces poverty more than growth driven by agricultural exports, which often bypasses small farms.

More broadly, the paper demonstrates that conventional theory on the role of agriculture in the early stage of development remains relevant to Africa. While the continent does face new and different challenges than those encountered by Asian and Latin American countries during their successful transformations, most African countries cannot significantly reduce poverty, increase per capita incomes, and transform into modern economies without focusing on agricultural development.

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The Role of Agriculture in Development: Implications for Sub-Saharan Africa

Xinshen Diao, Peter Hazell, Danielle Resnick, and James Thurlow[1]

I. INTRODUCTION

A majority of Sub-Saharan Africa's population live 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 this sector to the overall economy, it might seem obvious that agriculture should be a key component of growth and development. However, although agriculture-led growth played an important role in slashing poverty and transforming the economies of many Asian and Latin American countries, the strategy has not yet worked in Africa.[2] Most African countries have not yet met the requirements for a successful agricultural revolution, and factor productivity in African agriculture seriously lags behind the rest of the world. This has led to growing skepticism in the international development community about agriculture's relevance to growth and poverty reduction. This paper suggests that the 'agro-pessimism' not only is unwarranted but also undermines attempts to accelerate growth and poverty reduction. While parts of Africa are indeed disadvantaged by unfavorable natural and geographic conditions, agriculture's poor performance has often been due to underinvestment in physical, institutional, and human capital, as well as by attempts to bypass agriculture through isolated industrialization, often at the cost of agricultural stagnation and worsening poverty.

The aim of this paper is to examine whether the conventional wisdom on agriculture's role in the development process is applicable to the contemporary circumstances faced by a number of African countries. In particular, Section II of this paper analyzes how the perceived role of agriculture in development has evolved over the last half-century. It finds theoretical

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[2] 'Africa' here refers to 'Sub-Saharan Africa,' the regional focus of this paper.

and empirical justification for why 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. While there is a clear understanding of the conditions under which agriculture-led growth is most likely to succeed, many of these conditions either do not yet exist in Africa or need to improve further. However, the huge challenges facing African agriculture cannot be used as a justification for its neglect. Indeed, Section II highlights that little evidence or theory exists to suggest that Africa can bypass an agricultural revolution if the region is to substantially increase growth and reduce poverty.

Yet, while 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, Section III presents a typology of African countries classified according to the potential for agriculture to contribute to their growth. This typology is supplemented with in-depth case studies that examine the agriculture, growth, and poverty dynamics in Ethiopia, Ghana, Rwanda, Uganda, and Zambia. These case studies all highlight that broad-based agricultural growth, particularly in conjunction with growth in the nonagricultural sector, could contribute significantly to growth and poverty reduction. Within agriculture, the food staples subsector can offer the most poverty reduction in the five countries, particularly in the poorest subregions of the countries. Although 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, and improved governance. These and other conclusions are included in Section IV of the paper.

II. 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 often employs a majority of the labor force in most developing countries, the sector is integral to any thinking about development.[3] However, the perceived role of agriculture in growth and development has changed considerably over the last 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, agriculture's importance 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. Since natural resources were assumed to be freely available, early development theorists believed that agriculture could grow independently of other economic activities. However, in reality, agriculture's dependence on a fixed supply of land meant that its expansion was constrained. This implied 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 in order to avoid the Malthusian trap and stagnant development.

[3] Agriculture accounts for over 30 percent of GDP and 60 percent of total employment in Sub-Saharan Africa (excluding South Africa).

The need for agricultural growth during the early stages of development has also been examined in recent neoclassical literature. For example, Yang and Zhu (2004) use growth theory to capture the intertemporal dynamics of the development process. The authors demonstrate that, without agricultural productivity, a traditional economy cannot overcome the fixed supply of natural resources and thus, cannot generate sustained economic growth. Regardless of how fast the nonagricultural sector grows, stagnant agricultural production during the early stages of development prevents the structural transformation from a traditional to a modern economy.

Classical theorists observed that most developing countries are comprised of 'dual' economies. In this view, labor productivity is typically lower in agriculture than in industry, and hence development requires the movement of agricultural labor into nonagriculture. While nonagricultural innovation and technological change can occur independently of the agricultural sector, both labor and savings must be released from agriculture in order to satisfy labor demand and finance capital investment in industry. This explains "why industrial and agrarian revolutions always go together and why economies in which agriculture is stagnant do not show industrial development" (Lewis 1954, 433).[4] Furthermore, the fact that demand for agricultural goods does not keep pace with per capita income growth (Engel's Law) implies that agricultural surpluses can be generated as long as agricultural productivity growth exceeds the population growth rate.

Beyond agriculture providing a 'reserve army' of labor, classical economists also highlighted the importance of food supplies in stimulating economic growth. If traditional agriculture remains stagnant, then increased employment in the nonagricultural sector may result in 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).[5] The pressure to raise wages would hamper industrial growth, especially during the early stages of

[4] The observation that few countries have managed to develop without agricultural growth has been repeatedly asserted throughout the literature (see Lipton 2004).
[5] Open economies may use imports to overcome a food shortage, but this has historically been limited to entrepôt city-states like Hong Kong and Singapore.

development when technologies are typically labor-intensive. Increased labor costs eventually drive the economy into a 'stationary state' without further growth (see **Box 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 and 1964; and 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."

While 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 during the 1950 to 1970s. However, as will be discussed later, the 'urban-bias' generated by these attempts at industrialization revealed that agricultural and nonagricultural growth could not occur independently of each other.

Box 1. Food Availability Can Become a Constraint for Economic Growth

Latin American countries experienced rapid industrialization during the 1950s to 1970s. Agricultural growth barely matched rising food demand caused by high population growth and urbanization. Industrial growth rose to 8 percent per year between 1965 and 1973, 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 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).

Agriculture's Active Role in Growth and Development

The passive view of agriculture's role 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 agriculture's potential as a growth sector (see **Box 2**). Simultaneously, it highlighted that science-based technology adapted to a country's ecological conditions is key for agricultural growth. Indeed, advances in mechanical and biological technology can help overcome endowment constraints, particularly with 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.

The importance of intersectoral linkages in driving the growth process had already been widely recognized. Hirschman (1958) was one of the first theorists to emphasize linkage-effects in the growth process, although his analysis focused mainly 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 agriculture and nonagriculture. In particular, agricultural production generates forward linkages such that agricultural outputs are supplied as inputs into nonagricultural production. Growth in agriculture contributes to rapid rises in agroprocessing and processed food marketing, which not only provides new engines of growth but an opportunity 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 as an economy modernizes, but decline in relative importance alongside agriculture's share of production (Haggblade *et al*. 1989).

Box 2. Agriculture Explains More Than Half of GDP Growth Between 1960 and 1990

Work by Gollin *et al*. (2002) shows the importance of agriculture in the early stages of development. Using both cross section and panel data for 62 developing countries for the period 1960 to 1990, the authors find 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. Furthermore, 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.

The consumption linkage generated by increased rural incomes is agriculture's most important linkage in the development process (see **Box 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, it is unlikely that sufficient export opportunities will 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 urban growth demands agricultural growth may be less binding if imports can substitute for domestic agriculture. Nonetheless, agricultural

Box 3. Agricultural Linkages Change Across Different Stages of Development

Using social accounting matrices for 27 countries, Vogel (1994) examines the strength of the linkages between agriculture and the rest of the economy at different development stages. The author found that 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. At later stages of development the forward linkage strengthens due to a greater and more complex integration of agricultural production with other sectors.

growth has stronger links to the rest of the economy than nonagriculture (especially industry) because (i) agricultural output is typically sold in domestic markets, (ii) intermediate inputs into agricultural production are less import-intensive than industrial production, and (iii) rural demand is usually met by domestically-produced goods. On the other hand, 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. Admittedly, export-oriented agriculture can 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 can dampen agriculture's linkage-effects, especially in smaller and more open economies.

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 Haggblade 1982, 1991; Hazell and Roell 1983). This shift in emphasis was motivated by (i) imperfect or missing commodity and factor markets; (ii) rigidities in rural-urban factor mobility; (iii) high transport costs; (iv) the existence of rural nontradable sectors; and (v) rural unemployment and underemployment. It was suggested that agricultural productivity growth stimulates rural economies through 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 region-focused 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 growth linkage effects emanating from agricultural growth have proved most powerful when agricultural growth is driven by small farms, which dominate the rural economy and agriculture in most Asian and African countries. An impressive body of empirical studies has demonstrated that small farms are highly efficient due to their greater land productivity and their provision of self-supervising labor (for example., Eastwood *et al*. 2004, Hazell 2004). Small farms help 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. Furthermore, small- to medium-sized farm households typically have more favorable expenditure patterns for promoting growth of the local nonfarm economy, including rural towns. They spend higher shares of incremental income on rural nontraded goods than large-scale farmers, thereby generating greater demand for labor-intensive goods and services produced locally (Mellor 1976; Hazell and Roell 1983). Crucially, small farms also ensure a degree of food security in rural areas where high transport and marketing costs can drive up food prices, while at the national level, the higher land productivity of small farms has the potential to greatly help poor countries attain self-sufficiency in staples such as cereals, roots and tubers, and even livestock.

The strong linkage effects of agricultural growth suggest that the sector could lead to broader economic growth in some countries, even open economies, during the early stages of industrialization. Singer (1979) described a 'balanced-growth' strategy as one in which "national development of agriculture as the primary sector and developing industries with strong emphasis on agriculture-industry linkages and interactions." (Singer 1979, 27) The balanced-growth strategy was later relabeled as an agricultural-demand-led-industrialization (ADLI) strategy (Adelman 1984). The ADLI strategy stressed that increasing agricultural productivity expanded internal demand for intermediate and consumer goods produced by domestic industry and, in turn, helped support the drive towards industrialization. Such agricultural growth was geared towards increasing the incomes of the poorest members of society through increasing the supply of wage goods. By contrast, urban-biased industrialization was often 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 policy toward agriculture should shift "from surplus extraction to surplus creation and to the generation of demand linkages with the rest of economy." (Adelman, 1984, 939)

Theory has recently moved beyond the direct sectoral linkages described above. Recent studies have shown a positive link between nutrition and economic growth. Inadequate and irregular access to food increases malnutrition, reduces labor productivity and is tantamount to a disinvestment in human capital (Bliss and Stern 1978; Strauss 1986; Fogel 1994; Williamson 1993). For example, Nadav (1996) examined the importance of nutritional capital by extending Solow's growth model. Drawing on a sample of 97 countries, the author finds that nutritional levels have a large and highly significant impact on economic growth (see **Box 4**). This is consistent with Fogel (1991), who found that increased caloric intake reduced mortality and raised productivity amongst the working poor during the early stages of Western Europe's development. He 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)

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

Box 4. Nutrition is a Key Determinant of Growth

Arcand (2001) 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, the author finds that nutrition affects growth directly, through labor productivity, and indirectly, through improvements in life expectancy. Increasing per capita consumption of dietary energy supply to 2770 kcal/day in countries, which 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 finds 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.

Urban-bias in public policies has distorted investment incentives and created strikingly different marginal productivities of capital in urban and rural areas (Fan *et al*. 2004). Timmer (2004) suggests 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 towards stimulating agricultural growth also contributes to the generation of broader economic growth.

In addition, the unique decision-making 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. Abramowitz (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.[6] Likewise, Temple and Johnson (1996) proxy for social capability using the Adelman-Morris index of socioeconomic development. By controlling for income per capita, the authors show that countries with higher average economic growth rates between 1960 and 1985 had higher levels of initial social capability in 1960. In order to fully mobilize a country’s social capability during the early stages of development, it is important to acknowledge smallholder farmers’ entrepreneurial potential and accordingly develop technologies that improve their management capabilities. In turn, these rural entrepreneurs can help drive nonagricultural growth in both rural and urban areas.

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

Agricultural Growth Reduces Poverty

Given its size and composition, agriculture is important not only for generating growth but also for reducing poverty and inequality. As noted by Atkinson (1997), there is no unified theory of income distribution. Rather the empirical debate has revolved around the Kuznets (1955) hypothesis, which predicts that income inequality first rises and then falls with economic development. Kuznets based his speculation on longitudinal data on the industrial countries' development histories. Subsequent cross-country estimations have generally supported this hypothesis. However, recent and more sophisticated country-level analyses find no evidence of a systematic link between inequality and the rate of growth (Mellor 1999; Kanbur and Squire 2001). Lopez (2004), for example, in his cross-country estimation that explicitly accounts for countries' initial conditions finds that growth is most important for poverty-reduction during the earliest stages of development that is, at low income levels). However, the author's analysis suggests that inequality increasingly becomes a constraint to poverty-reduction at higher 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. Linking sectoral growth and poverty-reduction has become a focus in the literature (Mellor 1999). There is a large econometric literature from the late 1990s onwards that uses cross-country or time-series data to estimate sectoral and subsectoral growth-poverty elasticities (for example, Timmer 1997; Ravallion and Datt 1999). Agricultural growth, as opposed to growth in general, is typically shown to be the primary sector reducing poverty. Nonagricultural growth is found to have a greater impact on overall growth since these sectors have typically grown faster than agriculture.[7] However, in the early stages of development these high nonagricultural growth rates have typically been achieved only when agriculture is also growing rapidly. This is because the resources used for agricultural growth are only marginally competitive with other sectors, thus, fast agricultural

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

growth tends to be additive to growth in other sectors and is a stimulant of growth in the labor-intensive nontradable sectors (Mellor 1966 and 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 5**).

The strong poverty-reducing effect of agricultural growth is due in part to its generation of both agricultural and nonagricultural employment. As mentioned above, agriculture is by far the largest employer in developing countries where over half the labor force is typically directly engaged in agriculture. This is especially true in labor-abundant economies where small-farm households often account for large shares of the rural and total poor. 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. While 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.

Box 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 interhousehold 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 textiles subsectors within manufacturing made relatively large contributions to poverty alleviation by employing unskilled workers.

Using data for 1985 to 1996 for China, Fan *et al.* (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 only contributes 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) find that variables which 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 find that increasing agricultural productivity is the most efficient path for many countries to reduce poverty and inequality.

Lipton and Longhurst (1989) suggest that, in its initial stages, the Green Revolution raised the labor-intensity of agricultural production, although this higher labor demand was slowly eroded due to subsequent adoptions of labor-displacing inputs. Similarly, Bingswanger and Quizon (1986) find a relatively low but positive output elasticity of agriculture with respect to labor.[8] Growth in agriculture also results from a shift from low-value to high-value crop or livestock production. Most high-value crop production, such as 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. 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 Hazel 2000).

[8] Growth in agriculture also results from a shift from low-value crop to high-value crop or livestock production. Most high-value crop production (such as horticulture) and intensified livestock production are highly labor-intensive. 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. Part Two of this paper examines sectoral variations within agriculture in more detail.

Even though majority of the world's poor live in rural areas, it does not mean that they are solely engaged in farming. Farm households often derive incomes from nonfarm activities, although their contribution tends to be smaller than agriculture and is often indirectly agriculture-related (Ashley and Maxwell 2001). 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 those 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*. (1998) show 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).[9] While the importance of food-supply in the growth process has already been discussed above, its link to poverty reduction should be understood within the broader context of development. By benefiting the poor, agricultural growth can facilitate development by smoothing structural transformation and reducing potentially painful adjustment costs as inequality becomes more binding on growth later in the development process.

[9] 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.

Contemporary Skepticism about the Role of Agriculture in Africa

Despite the above theories and the number of Asian case studies that support them, there is doubt about whether agriculture can successfully generate enough growth in Africa today. 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 amongst development scholars about agriculture's relevance to growth is mainly based on the recognition of changed local and global conditions for Africa due to the impact of globalization. Some of the key positions promoted by this new breed of agricultural "skeptics" are elaborated below.

The availability of cheap and plentiful food imports can allow African countries to leapfrog agricultural development and proceed directly to industrialization

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 might appear to eliminate the need to modernize agricultural sectors. However, while 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 only become an engine of growth if the income generated from exports is channeled into productivity growth in nonnatural 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, since 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. First, 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 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 10-15percent of the labor force in Africa and its employment elasticity remains low compared to 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 seriously reduce 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, while fixed exchange rates are largely a thing of the past, growing food imports still pressure 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 pointed out that 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. While many of these policies were abandoned, an urban-bias orientation still influences public investment and policy priorities in many countries today. If the new "bypass" argument further influenced the investment policies of African governments and international donors, it would create huge challenges towards generating agriculture-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 argue 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 production sector that 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 towards improving the ease at 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 agricultural-based incomes remain stagnant.

Several reasons 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. Secondly, 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) note 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 threatens the ability of smallholding farmers to compete with large-scale, commercial farmers.

While this school is pessimistic about agriculture's potential, it provides few viable alternatives to the primary growth role played by 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 multioccupation and multilocation 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 from the farming of their own lands (Kenya 1977). A similar situation is also reported by Reardon *et al*. (1994) 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). On the other hand, in Africa, diversification into the nonfarm economy is often driven by growing land scarcity, declining wages, and poor agricultural growth (Haggblade *et al*. 2002; Start 2001). 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 (Thirtle *et al.* 2001; Collier and Gunning 1999). 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 many 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)

Most small farms cannot compete and remain viable in today's globalized markets and hence, they should not be the priority of future agricultural investment strategies.

Agricultural marketing chains are changing dramatically due 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. These changes offer new opportunities to small farmers who can successfully access and compete in these transformed markets, but they are also a serious threat to those who cannot.

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

Agricultural development should now focus on high-value commodities and value-added processing rather than food staples production.

With chronic global surpluses of major food staples and rapid expansion in international agricultural trade, many see high-value commodities such as fruits, flowers, vegetables and livestock 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). While 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, the greatest market potential for most African farmers still lies in domestic and regional markets for food staples (cereals, roots and tubers, 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 will add about US$50 billion per year to demand in 1996-2000 prices (**Table 1**). Moreover, with increasing commercialization and urbanization, much of this additional demand will translate into market transactions and not just additional on-farm consumption. There are no other agricultural markets that 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.

Table 1. Size of Sub-Saharan Africa's Agricultural Markets

	Market value (billions of $US)			
	Eastern Africa	Southern Africa	Western Africa	Total Africa
Traditional exports to non-Africa	2.2	2.4	4.0	8.6
Nontraditional exports to non-Africa	1.3	2.8	2.0	6.1
Other exports to non-Africa	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

Source: Trade figures are from UN COMTRADE (2002) and are 1996-2000 averages; domestic-market figures are for 2000 from FAOSTAT (2003). Domestic market demand includes the value of own consumption.

The public sector has a relatively minor (enabling) role to play in Africa's agricultural development, while the private sector should be in the driving seat.

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.

At that time, the public sector went far beyond a facilitating role and provided most key services itself, including research and development (R&D), extension, storage and marketing, and the supply of improved seeds, fertilizer, and credit. Moreover, the government intervened to stabilize prices for producers and consumers alike, and provided subsidies for many key inputs to encourage their uptake. These interventions also helped ensure that small farmers were able to participate, and this contributed greatly to the levels of poverty reduction achieved. The IFPRI calculations show that most of these policies and interventions had favorable benefit/cost ratios in the early years, but these ratios worsened over time once the interventions had served their primary purpose. Unfortunately, once institutionalized, it has proved very difficult to remove these interventions, and as input use increased, the costs to the governments soared. Today, for example, India spends about US$10 billion per year on unproductive subsidies.

The international development community is now so obsessed with post- Green Revolution problems that it is asking Africa to launch its own agricultural revolution without these public interventions. Africa is being asked to rely almost exclusively on the private sector and producer organizations. Is the international development community asking for the impossible? Is it drawing the right lessons from Asia? There is hardly any credible 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. There is also a growing body of studies showing that important institutional and market failures are to be expected at that level of development. It is a well-known fact that no Asian country developed its food staple agriculture from a subsistence to market orientation without heavy public intervention in the market chains.

This is not to advocate a return to costly and inefficient parastatals or to hefty and poorly targeted subsidies. Nor is it an argument against a strong role for the private sector where this can work, as in many high-value market chains. What is really needed is a much better understanding of those aspects of public intervention that really worked in Asia and why (for example, Dorward *et al*. 1998; Dorward *et al*. 2004). Then, important lessons can be drawn about the institutional innovations needed to bring those essential ingredients to Africa.

III. THE ROLE OF AGRICULTURE IN AFRICA: SELECTED COUNTRY CASE STUDIES

The previous section suggests that there is growing skepticism within the international development community over agriculture's potential contribution to growth in Africa. These arguments, which to some extent advocate bypassing agricultural development, may influence government and donor agencies' policies and investment strategies. Whether African countries believe they can bypass agricultural development, especially given cheap and plentiful food available in world markets, will directly influence priority-setting. Furthermore, pessimism concerning the role and competitiveness of small farms, which dominate African agriculture, will directly affect governments' agricultural investment strategies. Similarly, an optimistic perception of the potential role of high-value agricultural commodities and nontraditional exports may influence investment decisions and the allocation of limited resources.

Emerging skepticism is one school within the current debate over the role of agriculture in setting Africa's development priorities for the new millennium. An alterative school continues to support the importance of agriculture in Africa's development process. These proponents of agriculture emphasize that the sector has sufficient scale to make the necessary impact on aggregate growth and that the currently low levels of agricultural productivity implies that Africa has considerable potential to catch up to the competitiveness of other developing countries. Furthermore, agriculture's proponents highlight that, despite skepticism over agriculture and the resulting promotion of alternative sectors, agriculture, in fact, has performed better than other sectors in low-income African countries.

This section addresses the current debate between agriculture's skeptics and proponents. It provides empirical evidence on the importance of agriculture for growth and poverty reduction in Africa by conducting case studies in a number of low-income African countries. These are selected according to country typology so that general conclusions can be drawn.

A Typology of African Countries

The theoretical and empirical literature suggests that the role of agriculture is highly 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 (**Table 2**). Only eight percent of Africa's population lives in middle-income countries, where average GDP per capita is almost ten times higher than the average for low-income Africa (**Appendix**, **Table A4**).[10] Agriculture is less important in middle-income countries and on average generates less than ten percent of GDP. Higher average per capita incomes typically correspond to lower poverty rates, with middle-income countries in total containing less than one 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, while agriculture may not be a dominant sector in most middle-income economies, it still plays an important role in reducing poverty.

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 one 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 ten percent of GDP. Most private services are closely tied to agricultural and industrial production and, therefore, are unlikely to become engines of growth during the early stages of development.

[10] These countries are shown in the far-right column of the typology and have per capita GDP above US$1000 per year.

To better understand 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 (**Table 2**). Agricultural potentials draw on a classificatory scheme developed by Dixon *et al.* (2001) and include a range of measures such as agroecological conditions and population densities.[11] 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 nonagriculture. Therefore, coastal and landlocked countries are also separated. The typology, therefore, identifies four groups of low-income countries: (i) coastal, (ii) landlocked, (iii) mineral-rich; and (iv) 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, while 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 (**Table 2**). These countries have more favorable agricultural conditions, fewer natural barriers to trade, and their development is less likely to be driven by a 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 last 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. Therefore while

[11] See Tables A4 and A5 in the appendix for more details on the data underlying the typology.

agriculture's growth rate of 3.5 percent per year is lower than that of industry, the sector's contribution to overall GDP growth is larger.

Table 2. Cross-country Typology for Sub-Saharan Africa

		Agricultural share above average (34% GDP)		**Agricultural share below average** (34% GDP)		**Middle income countries** (> US$1000 p.c.)
		Falling GDP p.c. (1991-01)	Rising GDP p.c. (1991-01)	Falling GDP p.c. (1991-01)	Rising GDP p.c. (1991-01)	
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)	Cote d'Ivoire (14)	Kenya (24) Mozambique (33) Senegal (13)	Mauritius (5) South Africa (2)
	Landlocked country		Burkina Faso (57) Ethiopia (85) Malawi (51) Uganda (41)		Lesotho (41) Zimbabwe (52)	Swaziland (66)
	Mineral-rich country	Cameroon (40) C.A. Rep. (82) D.R. Congo (92) Sierra Leone (72)	Sudan (80)	Angola (72) Rep. Congo (52) Zambia (79)	Guinea (64) Nigeria (68)	Equi. 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 number in parentheses is national dollar-a-day poverty rate in 1999 (UNIDO 2004; World Bank 1995, 1997 and 2003). *Agricultural conditions* are based on FAO Farming Systems' potentials weighted by system's land coverage within each country (Dixon *et al*. 2004). Agriculture shares are for 2001 from World Development Indicators (World Bank 2003). Geographic and natural resource classification based on UNIDO (2004). Per capita GDP growth is measured in constant local currency. Per capita GDP is in US dollars (i.e., not international dollars). Six Sub-Saharan countries are excluded due to data-limitations (Eritrea, Liberia, Mayotte, São Tomé and Principe, Seychelles, and Somalia).

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, there are a number of outlier countries that 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.

Landlocked Countries without Large Mineral Resources

One of the characteristics of Africa is its large number of landlocked countries. The fourteen 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 countries lying in the Sahel. However, the second group of countries in the typology includes only those landlocked countries that have more favorable agricultural conditions and that do not have large mineral or oil resources (**Table 2**). 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 last 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 upwards 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 having similar initial conditions to 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, they have grown slowly over the last 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. 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 contains countries with both the highest and lowest GDP per capita amongst all low-income African countries. Although the industrial sector is larger in mineral-rich countries, almost 60 percent of the population still live 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 thus 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 those countries with less favorable agricultural conditions, regardless of whether they are landlocked, coastal or mineral-rich. Only ten 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, twice the contribution of industry. Furthermore, agriculture has grown substantially faster than industry over the last 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 industry.

Almost three-quarters of the population live 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 section 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 agriculture's contribution to growth and poverty reduction is examined and contrasted against alternative sources of growth. This is done 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, vulnerable to recurrent droughts, and are among the world's poorest countries. Agriculture contributes substantially to GDP and more than four-fifths of their populations live in rural areas (**Table 3**). By contrast, manufacturing contributes relatively little to GDP and is overwhelmingly 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 last 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 growth in both GDP and agriculture over a sustained period. Ghana in particular is one of only a handful of developing countries to have consistently maintained a positive per capita GDP annual growth rate over the last twenty years. Ghana is the only coastal country among the five case studies and has a relatively high share of industry to GDP due to agroprocessing, textile manufacturing, and gold mining. However, agriculture still generates one-third of GDP. Within agriculture, crops and livestock account for three-quarters of agricultural production, and are the primary activity of two-fifths percent of the population (Aryeetey and McKay 2004).

Table 3. Comparative Indicators Across the Selected Case study Countries

	Share of GDP (%) (1999)		GDP growth rate (%) (1985-99)		Poverty headcount (%)		
	Agric.	Industry	Agric.	Total	$1-a-day	National rate	
Ethiopia	52.3	11.1	2.7	1.8	85.2	51.1 (1992/93)	44.2 (1999/00)
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 (1999/01)
Uganda	36.4	20.9	3.5	9.0	40.8	56.0 (1991/92)	35.0 (1999/00)
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); Ministry of Finance and Economic Development, Ethiopia (2003); Ghana Statistical Services, Ghana (2000); Ministry of Finance, Rwanda (2002); Okidi *et al*. (2004); Thurlow and Wobst (2004).

Agriculture contributes less to GDP in Zambia than it does in the other four case study countries. This reflects the country's long-standing dependence on copper production and exports, which fostered a dualistic economy biased towards 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. Until the early 1980s, self-proclaimed socialist regimes in some of these countries frequently espoused an ideology of self-sufficiency, and aimed to keep food prices low for politically powerful urban constituents, finance import-substitution industrialization, and/or support rural producers through input subsidies and assured output markets. Yet, rather than improving agricultural technology and facilitating agriculture's positive linkages to the rest of the economy, the use of mechanisms such as inefficient marketing boards, overvalued exchange rates, and pan-territorial pricing resulted in agricultural stagnation or decline. These approaches 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. These induced foreign exchange constraints and higher food prices, which themselves dampened the industrialization process. Consequently, not only did agriculture suffer but so did other sectors in these economies.

Precipitated either by economic crisis or political change, most of these countries eventually adopted structural reforms during the 1980s and 1990s. These reforms 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. While 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. The outcome of long-term, urban-biased investments and polices 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 towards 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 last decade. As seen in **Table 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 in its recovering process from 1994's genocide. In Zambia, poverty declines in rural regions were accompanied by poverty increases in urban areas due 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 economy-wide models developed for each country. The following section describes the major features of the models and how micro-level poverty data are integrated with macro-level growth data.

The Economy-wide Models and Data Sources

The country studies are based on economy-wide simulation methods. Two different types of models are used for the country studies: economy-wide 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 for each country. Only in Uganda and Zambia was there 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 and poverty linkages can be conducted at the subnational level. For example, in the remote regions where the rural economy is dominant and poverty is high, the growth-poverty linkages may be different than in regions with high levels of urbanization and concentrated industrial production and urban employment.

There are many producers and consumers in each of the country models. These are aggregations from the most recent nationally-representative household survey. The aggregations reflect the heterogeneity of production and consumption patterns across subnational regions and between rural and urban areas. If data is available, the producers or consumers in the models are further aggregated according to other economic or social indicators captured in the household survey data (for example, according to sources of income, labor markets, gender, or other household characteristics). In both types of the models, the agricultural and manufacturing sectors are relatively disaggregated in order to analyze growth-poverty linkages at the subsector levels and across subnational regions.

While the economy-wide models already capture much of the heterogeneity across regions and rural and urban areas, the detailed information contained in the household surveys is not fully utilized. Therefore in order to retain this detailed information, a microsimulation model is linked with each country's economy-wide model in order to analyze how growth at the national and subregional levels influences poverty at the detailed household level. These microsimulation models capture household-level heterogeneity in income sources, participation in economic activities, and consumption expenditure patterns. By linking microsimulation models with economy-wide models, a similar national GDP growth rate can result in different poverty and distributional outcomes. A detailed description of the models, their underlying data sources, and how the national growth can affect household level poverty is provided in the appendix. In the following sections the models are used to examine growth-poverty linkages at the sectoral level, or in other words, how agricultural and industrial growth influences the rate of poverty reduction in the five case study countries.

Agricultural Growth is More Pro-poor than 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 now widely understood that most African countries are unlikely to meet the first

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

Millenium Development Goals (MDG) 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 is maintained, then the poverty headcount rate is likely to remain unchanged at around 44.3 percent by 2015 (cf. **Table 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, 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** shows that the poverty-growth elasticity is consistently larger when additional growth is driven by agriculture rather than nonagriculture. 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 nonagriculture leads to only 0.73 percent fall in the poverty rate. These disparities in poverty-growth elasticities can translate into significantly different reductions in the

[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 shown below

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

where $\Delta P0$ 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 one-percent increase in per capita GDP. This is *not* equivalent to a percentage point change in the poverty headcount rate.

poverty headcount over time. For example, with similar GDP growth, the poverty headcount in Ethiopia falls to 26.5 percent under the agriculture-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 due to heterogeneity across regions and households. With different income sources and locations within a country, changes in income and consumption across households can 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 account for changes in the distribution of incomes, which is primarily determined by country-specific initial conditions. For example, in some countries agriculture contributes a large share to 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 nonagriculture or export agriculture. Since such households are usually less poor than remoter households, economic growth driven by nonagriculture or agricultural exports may have less of an 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, while 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 these circumstances, agricultural growth is expected to be more pro-poor than nonagricultural growth since it is a more important income source for the poor.

Agricultural growth can also benefit urban and landless rural households if rising agricultural productivity lowers food prices. This is particularly important for poor urban and landless 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 (i.e., 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. On the other hand, 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 with identical underlying assumptions.

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

Table 4. Comparison of Agricultural and Nonagricultural Growth Scenarios

	Baseline scenario	Agriculture-led scenario	Nonagriculture-led scenario
Ethiopia (2003-2015)			
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 (1000)		-15,904	-6,280
Poverty-growth elasticity	-	-1.66	-0.73
Ghana (2003-2015)			
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 (1000)		-1,722	-586
Poverty-growth elasticity	-1.49	-1.78	-1.33
Rwanda (2003-2015)			
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 (1000)		-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 (1000)		-3,993	-2,388
Poverty-growth elasticity	-0.98	-1.58	-1.10
Zambia (2001-2015)			
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 (1000)		-1,253	-529
Poverty-growth elasticity	-0.35	-0.58	-0.38

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

The large gap between the poverty-growth elasticities in the two scenarios reported in **Table 3** indicates the relative importance of agricultural growth, especially for poorer rural households. Agriculture's proponents 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 nonmining industrial sectors, is less effective at reducing poverty than an agriculture-led growth strategy. As seen in **Table 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 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 cocoa sector has still received priority attention over food crops. While such high-value agriculture may have greater potential to grow, 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 compose almost 65 percent of agriculture. Along with livestock, a majority of Ethiopia's poor depend heavily on cultivating these staple crops. This is equally true in Rwanda, where the share of staples 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 it is 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. This is done empirically using applied economy-wide models that determine the poverty reduction resulting from accelerating growth in each of the two sectors.

Assuming similar growth rates at the subsector level, greater economy-wide growth will be obviously 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. In order 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, in order for export crops alone to generate an additional one percent annual growth in aggregate GDP (from four to five percent), these crops would have to grow at 23 percent per year because this subsector is initially very small (**Table 4**). By contrast, the staples sector is substantially larger and so does not have to grow as rapidly to achieve the same additional one percent annual growth in GDP. Similarly, to achieve five percent growth in annual agricultural GDP in Ethiopia, the required growth rate for the staple crops is five 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 true 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 five 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 five percent of agricultural growth. Therefore, despite generating the same aggregate growth rate, accelerated staples-led growth is able to lift additional four million people out of poverty by 2015.

While growth in the staples sector can play a critical role in reducing poverty, past growth in this sector has typically risen from area expansion within the five case study countries. There is an extensive literature that tries to identify the key factors capable of increasing staple sector productivity. Many studies, focusing on the farmers incentives to increase productivity, find that declines in the provision of credit from the banking sector and low accessibility to modern inputs are among the main factors affecting farmers' incentives. These problems 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 rural areas, especially in areas dominated by subsistence production. For example, in Ghana's arid rural savannah zone, the population 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 only experienced a slight decline in its poverty headcount from 73 in 1991 to 70 percent in 1999.

Table 5. Comparison of staples and exportable agricultural growth scenarios

	Baseline scenario	Staple-crops-led scenario	Export-crops-led scenario
Ethiopia (2003-2015)			
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
Staples crops	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 (1000)		-15,279	-11,313
Poverty-growth elasticity	-	-1.80	-1.40
Ghana (2003-2015)			
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
Staples crops	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 (1000)		-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
Staples 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 (1000)		-3,602	-3,445
Poverty-growth elasticity	-0.98	-1.40	-1.39
Zambia (2001-2015)			
Annual per capita GDP growth rate (%)			
Annual GDP growth rate (%)	4.0	5.0	5.0
Agriculture	4.6	7.8	7.1
Staples 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 (1000)		-1,210	-842
Poverty-growth elasticity	-0.35	-0.57	-0.47

Source: Authors' simulations and calculations.
Note: Given that exportable sector is too small in Rwanda, we do not include Rwanda in these simulations
1. Livestock is included
2. Only nontraditional exportable crops are included

Poor infrastructure and limited access to input and output markets also pose severe constraints for small farmers to access new technology and improve both land and labor productivity. Poor market conditions and high transportation costs often imply that increased food production will simply lower the price that farmers received for their produce. This further reduces the incentive to adopt the high yield/productivity technology often required for intensive use of purchased inputs. Findings from the Ethiopian and Zambian economy-wide models suggest that if staples growth is combined with a lowering of transaction costs through public investments, then poverty reduction would be substantially improved (Diao et al. 2005; Thurlow and Wobst 2004).

IV. THE WAY FORWARD FOR AFRICAN AGRICULTURE

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 pre-condition for industrialization because the sector provides surplus labor to industry, savings for capital investment in nonagriculture, 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 the largest employer in most developing countries, agricultural growth 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.

Agriculture's pro-growth and pro-poor performance depends on small farms being in the vanguard. 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 that an agriculture-led strategy in general, and a small farms one in particular, is a viable approach. Nevertheless, there is little evidence or theory to suggest the superiority of other strategies, such as bypassing agriculture straight to industrialization or encouraging migration 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 2**. 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 those 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 Section II, agricultural growth in these countries creates greater linkages and hence generates more poverty reduction than growth in the nonagricultural sector alone. Overall though, increased productivity in agriculture and nonagriculture together offers the greatest prospects for generating broad, economic development and decreasing poverty.

While 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 those areas with good irrigation and convenient access to markets. Yet, in all five countries, staples growth consistently offered more poverty reduction than any of the other subsectors. For most African countries, especially those with large populations such as Ethiopia, agricultural and other economic growth will depend on growth in domestic markets. Domestic demand on staple foods, which provide the bulk of that market, is projected to double within the next 15 years (Diao and Hazell 2004). Increases in farm income obtained by capturing such market opportunities will be greater than those offered by niche markets.

Yet, how can agriculture's potential be translated into a reality? A number of studies have identified the preconditions for an agricultural transformation. On the supply-side, innovations in science and technology are necessary to counter erratic rainfall, declining soil fertility, and production growth due to land expansion rather than technical change. This is perhaps most crucial in many African countries in which agricultural growth often resulted from land expansion. Lack of profit opportunities in the technology for food grains and inputs for small-scale agriculture often deters the private sector in the early stage of development, and hence, public investments in agricultural R&D are needed. Evidence from rural Uganda indicates that public investments in agricultural R&D had the highest impact on poverty reduction throughout the 1990s (Fan and Rao 2004). In addition to financial resources, agricultural innovation requires human capital and, therefore, sustaining and improving upon advances in agricultural R&D requires concurrent investments in general education (Hayami and Ruttan 1985).

As the case studies highlight, greater public investment in rural infrastructure is also necessary in order 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. As shown by Fan *et al.* (2004) for rural Uganda, infrastructure investments do not have to be excessive to have a sizeable impact. Indeed, dollar for dollar, investments in feeder roads reduced the number of poor Ugandans by over 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).

Many skeptics believe that the enormity of investments and policy changes needed to ensure agricultural growth in Africa justify bypassing the sector. Yet, there are two reasons to dismiss this pessimism. First, as highlighted by Gabre-Madhin and Haggblade (2004), there have been notable successes in African agriculture in terms of increased R&D, improved environmental conservation techniques, and the seizing of new market opportunities. Secondly, many of these investments and policies are also essential to stimulate growth in sectors outside of agriculture and, therefore, are unavoidable if the intention is to create broad, economic development. In the past, the necessary components for agricultural growth were largely neglected in favor of capital-intensive, fast-track industrialization strategies. While new challenges face the sector today, they must be tackled rather than ignored in order to ensure that millions of Africans finally have a pathway out of poverty.

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APPENDIX: DATA SOURCES AND MODEL SPECIFICATIONS

Two different types of models are used in this study: economy-wide multimarket models (Ethiopia, Ghana and Rwanda) and computable general equilibrium 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 economy-wide multimarket model (EMM) and the computable general equilibrium (CGE) model.

Data Sources and Aggregation for the Economy-wide, Multimarket (EMM) and CGE Models

The EMM places greater emphasis on capturing the detailed structure of the agricultural sector. This can be seen in **Table A1**, which shows that of the 34 sectors identified in the Ethiopian EMM model, 32 of these are agricultural sectors. 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 sectors, 9 are industrial sectors, and 5 are service sectors. However, while the CGE models are better at capturing cross-sector growth-linkages during the production process, they sacrifice information on the detailed production technologies used in the various agricultural sectors. These differences may not prove too significant, however, since 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 in the models and are linked directly to the household survey to ensure that the most detailed household information is retained.

The models are also disaggregated across regions within each country in order to capture the geographic heterogeneity of sectors and households. In this regard, the EMM models are considerably more disaggregated than the CGE models. However, both types of models are constrained by the representativity of the underlying household and production data and so cannot present results beyond the main administrative provincial or regional levels.

Specification of the Economy-wide Multimarket (EMM) Models

Nontechnical Description and General Assumptions

Only the specification of the Ethiopian model is presented since the models for Ghana and Rwanda are similar in structure. The EMM model is based on neoclassic microeconomic theory. In the model, there are representative producers who are aggregated to represent the zonal level production for both rural and urban areas. The supply functions that are derived from producer-profit maximization are functions of producer prices across 34 commodities. In the agricultural sector, supply functions have two components: (i) yield and area functions and (ii) land allocation responsive to changing profitability across different crops given total land available in the period.

Representative consumers are aggregated from the household survey data to represent an average household's consumption pattern at the zonal level, again with a rural and urban disaggregation. The demand functions derived from utility maximization depend 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, even though imported maize is assumed to be perfectly substitutable with domestically produced maize in consumers' demand functions, due to high transportation and other market costs, maize may not be profitable to import if the domestic price for maize is lower than the border price of maize less any transactions costs. Maize imports can only occur when the domestic demand for maize

Table A1. Sectors, Households and Regions in the Models

Ethiopia	**Economy-wide 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, 1997/98-2000/2001 (Central Statistics Authority) Agricultural Sample Enumeration, 2001/2002 (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	**Economy-wide 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)

Table A1 contd. Sectors, Households and Regions in the Models

Rwanda	**Economy-wide 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; Beverage; 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)
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 agro-ecological zones and one nonfarm household).
Data sources	Uganda National Household Survey, 1999 (UNHS-1) Uganda Social Accounting Matrix, 1999 (IFPRI) World Bank (for sector GDP, population and labor force trends) FAOSTAT (for trends in agricultural yields)

Table A1 contd. Sectors, Households and Regions in the Models

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-scale and nonfarm households); and urban (low, medium and high cost of living areas)
Data sources	Living Conditions Monitoring Survey, 1998 (LCMS II) Zambia Social Accounting Matrix, 2001 (IFPRI) IMF (for population and labor force trends) and World Bank (for GDP trends) FAOSTAT (for trends in agricultural yields)

increases faster than the growth in domestic supply of maize and the domestic market price rises significantly. A similar situation is assumed for exported commodities. Even though certain horticultural products are exportable, if domestic production is not competitive in international markets, either due to low productivity or high market transportation costs, then exports will not be profitable. In other words, only when domestic producer prices plus market costs are lower than the border 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 a zone as being in food surplus or deficit by comparing zonal level demand and supply for total food commodities. While producers and consumers in different zones operate in the same national markets for specific commodities, prices can vary across regions due to differences in transportation and market costs. For example, domestic marketing margins are defined at the zonal level according to the distance from each zone 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 due 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 'a-dollar-a-day' measure.[15] National poverty lines are typically measured by total household expenditure rather than income, since income is often significantly underreported in developing countries. However, changes in the representative households' expenditures in the EMM model 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 fully capture consumption patterns at the detailed household level. The Household Income, Consumption and Expenditure Survey (HICES), 1999/2000 is used in the microsimulation model, which is linked with the EMM model. More specifically, each household in the microsimulation model (equivalent to the HICE data set) links with its corresponding representative consumers in the EMM model, which in turn are defined at the zonal level for both rural and urban areas. There are 56 zones in the Ethiopia EMM model, and after further disaggregating across rural and urban areas, there are a total of 112 aggregate households. Taking a single household, "rural West Tigray" as an example, this aggregate household in the EMM model is an aggregation of 143 sample rural households in the HICES, weighted by their sample weights (which range from 903 to 1359).

A top-down linkage is defined from the EMM model to the microsimulation model. If results from the EMM model indicate that a 1 percent increase in per capita GDP causes a 1.3 percent increase in annual spending on teff for the "rural West Tigray"

[15] National poverty lines are preferable since they account for country-specificity in defining poverty. As was the case in constructing the typology, the dollar-a-day poverty measure is only used for cross-country comparison.

household in the EMM model, then there will be a 1.3 percent increase in spending on teff by all 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, the 1.3 percent increase will affect each of the 143 households differently depending on the budget share of teff in their consumption basket. The effect on total household expenditure will be larger for a household that spends more of its income on teff than for others who spend less. These differential effects occur across all 34 commodities included in the EMM model. It is by these differential effects that the EMM model, together with the microsimulation model, is able to estimate national 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 the real expenditure (for example, $96 per year per capita for rural households in Ethiopia), some poor households whose per capita expenditure is initially below the poverty line may move out of poverty in a certain year if their expenditure rises above the poverty line in the simulation for this year. Using the microsimulation model, the national poverty rates are recalculated according to updated total expenditure for each sample household (taking into account its weight) for each year in a simulation.

Mathematical Specification

(i) Supply Functions

Yield Function (for crops)

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

where $Y^{q}_{R,Z,i,t}$ is the yield for crop *i* with technology *q* in region *R* (total 11 regions) and zone *Z* (total 56 zones) at time period *t*, and $P_{R,Z,i}$ is the producer price for *i* and can be different across regions or zones. $YA^{q}_{R,Z,i,t}$ is the productivity shift parameter, which varies according to different technologies, q. $\mathrm{YA}^{q}_{R,Z,i,t}$ could be estimated as a function of modern inputs, such as irrigation, fertilizer, and improved seed, were more data available. Currently, the model only captures the mean difference across technologies. There are a total of 15 different technologies for the major (mainly cereal) crops, which implies that there are 15 yield functions per crop per zone; maize, for example, is characterized by the different level of $\mathrm{YA}^{q}_{R,Z,i,t}$, which changes over time:

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

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

Area Function (for crops)

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

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

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

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

$$S_{R,Z,i,t} = \sum_{q} Y^{q}_{R,Z,i,t} \cdot A^{q}_{R,Z,i,t}. \tag{5}$$

Supply Function for Noncrop Sectors (livestock and nonagriculture)

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

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

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

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

With regional disaggregation and commodity details, it is infeasible to estimate the supply elasticities used in the model. Thus, a modest own-price elasticity of 0.2 is chosen for the supply function.[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 zonal 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.

(ii) Demand Functions

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

$$Dpc_{R,Z,i,t} = \prod_j PC^{\varepsilon_{R,Z,i,j}}_{R,Z,j,t} GDPpc^{\varepsilon^{I}_{R,Z,i}}_{R,Z,t} , \tag{8}$$

where $Dpc_{R,Z,i}$ is per capita demand for commodity i in region R and zone Z, and $PC_{R,Z,j}$ is the consumer price for j in region R and zone Z. j = 1,2,…,36 (including two aggregate nonagricultural goods.) $GDPpc_{R,Z}$ is per capita income for region R and zone Z's rural or

[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.

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 $\sum_{j}^{J} \varepsilon_{R,Z,i,j} + \varepsilon^{I}_{R,Z,i} = 0$, and $\sum_{j}^{J} sh_{R,Z,j} \cdot \varepsilon^{I}_{R,Z,j} = 1$, where $sh_{R,Z,i}$ is the expenditure share of commodity *i*. Income elasticity is estimated using HICES data for the rural and urban. Due 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.

(iii) Relationship Between Producer and Consumer Prices

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

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

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

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

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:

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

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

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

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

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

(iv) Exports and Imports

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

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

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

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

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

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

(v) Regional Crop Deficit and Surplus

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

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

(vi) Balance of Demand and Supply at the National Level

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

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

(vii) GDP and Per Capita Zonal Income Function

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

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

Income per capita:

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

(viii) 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 zone *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 population $Pop^{rur}_{R,Z,h,t}$ of household group h equals the sample weights multiplied by the household size, represented by the sample household for group h updated with the population growth rate. Hence, the income of household group h is defined as:

$$I^{rur}_{R,Z,h,t} = Sh^{rur}_{R,Z,h} \cdot GDP^{rur}_{R,Z,t}; \sum_h Sh^{rur}_{R,Z,h} = 1. \quad (20)$$

$I^{rur}_{R,Z,h,t}$ 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

$$Ipc^{rur}_{R,Z,h,t} = \frac{I^{rur}_{R,Z,h,t}}{Pop^{rur}_{R,Z,h,t}}. \quad (21)$$

For the population $Pop^{rur}_{R,Z,h,t}$ in group h is in the poor if $Ipc^{rur}_{R,Z,h,t} < PoorInc^{rur}$. (22)

Two factors affect $I^{rur}_{R,Z,h,t}$ in the simulations, $GDP^{rur}_{R,Z,t}$ and $Dpc^{rur}_{R,Z,h,i,t}$. While $GDP^{rur}_{R,Z,t}$ is directly solved from the EMM model, and changes in $Dpc^{rur}_{R,Z,h,i,t}$ is assumed to be proportional to the same commodity consumed by the representative rural household in the same zone. For example, if consumption of teff increases by 1.3 percent at t = 2006 for the rural household in zone of West Tigray due to 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 the 143 sample households in the rural West Tigray household 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 households 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 others who spend less income on teff. These differential effects occur across all the 34 commodities included in the EMM model. With such changes, a household whose family members' total expenditure, $Ipc^{rur}_{R,Z,h,0}$, is lower than $PoorInc^{rur}$ initially, it is possible for it to move out off the poverty, if its family members' total expenditure, $Ipc^{rur}_{R,Z,h,0}$, higher than $PoorInc^{rur}$ at $t = 2006$, i.e., $Ipc^{rur}_{R,Z,h,2006} > PoorInc^{rur}$.

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 country as a whole.

Specification of the Computable General Equilibrium (CGE) Models

The poverty and distributional impact of alternative development strategies is modeled in Uganda and Zambia using an extended version of the static CGE model described in Lofgren *et al*. (2001) and the recursive dynamic CGE model described in Robinson and Thurlow (2004). The extensions include (i) the explicit disaggregation of economic activities at the regional level, (ii) imperfect and nested labor and land markets, and (iii) considerable disaggregation of households according to the economic and social characteristics. This class of model developed from the neoclassical modeling tradition originally presented in Dervis, de Melo and Robinson (1982). Since both countries' CGE models are built on a similar model structure, only the Zambian CGE model is described in this appendix. The structure of the Ugandan model is outlined in **Table A1**.

Nontechnical Description and General Assumptions

In accordance with the Zambian social accounting matrix (SAM), the model distinguishes between 27 sectors/commodities. However, given the explicit specification of subregions in the model, there are a total of 243 productive activities (that is, 27 sectors by nine provinces). While production activities are defined at the regional or provincial level, an integrated national market for commodities is assumed. That is, the model does not capture interregional trade within the country. Imperfect factor markets are assumed for land and unskilled labor, and the markets for these factors are defined at the regional or provincial level (that is, there is no free movement of factors *between* regions). By contrast, national capital is mobile across regions. There are three kinds of capital distinguished in the model: agricultural, mining, and other nonagricultural capital. The 243 representative producers in the model make decisions in order to maximize profits, but are constrained by factor market imperfections when choosing inputs. A two-level production system is employed. At the lower level, a constant elasticity of substitution (CES) function is defined over factors, while at the higher level, fixed-share intermediates are combined with the value-added in a Leontief specification. Profit maximization implies that the factors receive income where marginal revenue equals marginal cost based on endogenous relative prices.

Substitution possibilities also exist between production for the domestic and the foreign markets. This decision of producers is governed by a constant elasticity of transformation (CET) function which distinguishes between exported and domestic goods, and by doing so captures any time or quality differences between the two products. Profit maximization drives producers to sell in those markets where they can achieve the highest returns. These returns are based on domestic and export prices (where the latter is determined by the world price times the exchange rate adjusted for any taxes). Under the small-country assumption, Zambia is assumed to face a perfectly elastic world demand at fixed world prices. The final ratio of exports to domestic goods is determined by the endogenous interaction of relative prices for these two commodity types.

Further substitution possibilities exist between imported and domestic goods under a CES Armington specification. Such substitution can take place both in final and intermediates usage. The Armington elasticities vary across sectors, with lower elasticities reflecting greater differences between domestic and imported goods. Again under the small country assumption, Zambia is assumed to face infinitely elastic world supply at fixed world prices. The final ratio of imports to domestic goods is determined by the cost minimizing decision-making of domestic demanders based on the relative prices of imports and domestic goods (both of which include relevant taxes).

The model distinguishes between various 'institutions' within the Zambian economy, including enterprises, the government, and many representative households. These households are derived from the national household survey by aggregating across the nine provinces and, within each province, according to other socioeconomic characteristics. In total there are 63 aggregate households in the model (**Table A1**). Households and enterprises receive income in payment for producers' use of their factors of production. Both institutions pay direct taxes to government (based on fixed tax rates), save (based on marginal propensities to save), and make transfers to the rest of the world. Enterprises pay their remaining income to households in the form of dividends. Households, unlike enterprises, use their income to consume commodities under a linear expenditure system (LES) of demand.

The government receives income from imposing activity, sales and direct taxes and import tariffs, and then makes transfers to households, enterprises, and the rest of the world. The government also purchases commodities in the form of government consumption expenditure, and the remaining income of government is (dis)saved. All savings from households, enterprises, government, and the rest of the world (foreign savings) are collected in a savings pool from which investment is financed.

The model includes three broad macroeconomic accounts: (i) the savings and investment account, (ii) the current account, and (iii) the government balance. In order to bring about balance between the various macro accounts, it is necessary to specify a set of 'macroclosure' rules that provide a mechanism through which macroeconomic balance can be achieved. A savings-driven closure was assumed in order to balance the Zambian savings-investment account. Under this closure, real investment quantities are fixed, and the marginal propensities to save of households and enterprises adjust to ensure that the level of investment and savings are equal at equilibrium. For the current account it was assumed that a flexible exchange rate adjusts in order to maintain a fixed level of foreign savings. In other words, the external balance is held fixed in foreign currency indicating the government is not able to borrow in order to cover additional expenditure. Finally, the domestic price index was chosen as the numéraire. In the government account the level of direct and indirect tax rates, as well as real government consumption expenditure, are held constant. As such the balance on the government budget is assumed to adjust to ensure that public expenditures equal receipts.

On the microeconomic side, firms are assumed always to be on their factor demand curves. In the Zambian model it was assumed that all land and labor is fully employed and hence is paid a flexible real rental rate or wage under the condition of fixed supply. Capital is constrained to be sector-specific and earning flexible activity-specific returns.

In order to account for the full 'dynamic' effect of policy and nonpolicy changes, the static model described above is extended to a recursive dynamic model in which selected parameters are updated based on the modeling of intertemporal behavior and results from previous periods. Current economic conditions, such as the availability of capital, are endogenously dependent on past outcomes but remain unaffected by forward-looking expectations. The dynamic model is also exogenously updated to reflect demographic and technological changes that are based on observed or separately calculated projected trends. Most of these time-trends are taken from the World Bank's Zambian Revised Minimum Standards Model (RMSM) as described in detail in Lofgren *et al*. (2004).

The process of capital accumulation is modeled endogenously, with previous-period investment generating new capital stock for the subsequent period. Although the allocation of new capital across sectors is influenced by each sector's initial share of aggregate capital income, the final sectoral allocation of capital in the current period is dependent on the capital depreciation rate and on sectoral profit-rate differentials from the previous period. Sectors with above-average capital returns receive a larger share of the new capital stock than their current share in capital income. The converse is true for sectors where capital returns are below average.

Population growth is exogenously imposed on the model based on separately calculated growth projections. It is assumed that a growing population generates a higher level of consumption demand and, therefore, raises the supernumerary income level of household consumption within the LES demand system. Both labor supply and total factor productivity (TFP) growth are updated exogenously based on AIDS-adjusted estimates (see Lofgren *et al*. 2004). Finally, mining production is assumed to be predominantly driven by a combination of changes in world demand and prices, and other factors external to the model. Accordingly, GDP growth in these sectors and in the world price of exports are updated exogenously between periods based on detailed sector-level projections (World Bank 2004).

The dynamic model is solved as a series of equilibria each one representing a single year. By imposing the above policy-independent dynamic adjustments, the model produces a projected or counterfactual growth path. Policy changes can then be expressed in terms of changes in relevant exogenous parameters and the model is re-solved for a new series of equilibriums. Differences between the policy-influenced growth path and that of the counterfactual can then be interpreted as the economy-wide impact of the simulated policy.

The poverty and distributional impact of sectoral growth are modeled inside the same 1998 LCMS household survey that was used to construct the CGE model. As in the EMM models, a microsimulation model that fully employs the household survey data is linked to the CGE model. Each representative household in the CGE model is linked to its corresponding household within the microsimulation model (that is, the households in the national survey). Similar to the use of sample weights in the survey, each 'representative' household in the CGE model is an aggregation of a larger number of households. Since poverty in this study is defined according to per capita expenditure, changes in household expenditure from the CGE model are passed down to the survey, where poverty and inequality are calculated in the same way as described in the EMM model.

Mathematical Specification

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 without factoring future expectations into their current decision-making. The dynamics of the model involve updating the subsequent-period's parameters 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 B2 and B3 at the end of this section of the appendix. The mathematical equations forming the static model are broken down into sections. Initially the production and price structure of the model is described, which includes the determination of import and export demand (Equations 23 to 49). 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 50 to 59). The third and final block describe the equilibrium conditions imposed on the model (Equations 60 to 65). The remaining equations (66 to 71) 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 23 and 24, where the aggregate quantity of intermediates for an activity ($QINTA_a$) is composed of the fixed shares of the individual intermediate commodities used in that activity's production ($QINT_{c\,a}$). 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 pre-determined 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, therefore, is 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 43.

Unlike the Leontief treatment of intermediates, factors are combined into a composite primary factor under a CES function (Equations 25 and 26), which combines the factor demands of an activity ($QF_{f\,a}$) into an aggregate quantity of value-added inputs for that activity (QVA_a). This 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 $\alpha_{f\,a}^{vaf}$.

Demand for individual factors at lower levels of the nested demand system are given in Equations 27 and 28, where 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 29 and 30) to arrive at a final level of output for each activity (QA_a). This production function is strongly separable, since the 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 31 where 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).

Since each activity can produce more than a single commodity, Equations 32 and 33 convert each activity's output and price into a commodity output ($QXAC_{a\,c}$) and price ($PXAC_{ac}$) based on fixed shares ($\theta_{a\,c}$). 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 34 and 35 show the CES aggregation function and its first-order conditions. In these equations output from each activity ($QXAC_{a\,c}$) is combined across activities to form a composite commodity output (QX_c). Similarly the composite output's price (PX_c) is the aggregation of each activity's commodity price ($PXAC_{a\,c}$).

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 36, 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 sold both domestically and abroad, Equations 37 and 38 represent the constant elasticity of transformation (CET) function determining the quantity and price of exported and domestically sold commodities. These equations represent the ease at which producers are able to substitute production between the two markets. Domestic and foreign commodities become more homogenous as the elasticity of transformation increases towards 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. However larger shifts in production towards a different market 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 39 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 40, 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 41 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 ($PQ_{c'}$).

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 42, 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 43 and 44 represent the constant elasticity of substitution (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 45 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 46 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 47). A fixed quantity of trade inputs are used per unit of the commodity being traded. These are shown in the equation as $icm_{c\,c'}$ for imports, $ice_{c\,c'}$ for exports, and $icd_{c\,c'}$ 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 (48 and 49) 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 homogenous 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 50. Total income for each factor (YF_f) is equal to its economy-wide wage (WF_f) multiplied by both the quantity employed ($QF_{f\,a}$) in each activity and its sector-specific wage-distortion term ($WFDIST_{f\,a}$). Factor incomes are then either transferred to domestic institutions or to the rest of the world. Equation 51 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 ($shif_{i\,f}$) to arrive at a total value of factor income for each institution ($YIF_{i\,f}$).

Direct payments from factors ($YIF_{i\,f}$) only form part of the total income (YI_i) earned by domestic nongovernment institutions. As shown in Equation 52, other income sources include transfers received from other institutions ($TRII_{i\,i'}$), 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 ($TRII_{i\,i'}$) in Equation 53. 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 ($shii_{i\,i'}$) of the institution's income ($YI_{i'}$) after paying taxes ($\overline{tins_{i'}}$) and savings ($MPS_{i'}$).

Having determined households' income, Equation 54 calculates the amount of income available for consumption spending (EH_h). This 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 ($shii_{i\,h}$). 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 ($QH_{c\,h}$) is a linear function of total spending (EH_h). Total household expenditure is distributed across commodities in Equation 55. 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 across 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 56 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 57). This 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 ($PQ_c \cdot QG_c$), as well as CPI-indexed transfers to other institutions ($trnsfr_{i\,gov} \cdot \overline{CPI}$) (Equation 58). Government expenditure is financed by government revenue (YG). As shown in Equation 59, 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 60 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 61, 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: (i) factors are mobile across sectors but total supply is fixed; (ii) factor supply is fixed and factors are immobile across sectors; or (iii) 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 below) 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 62. 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 (i.e., 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 57), and the level of government income from the direct taxation of domestic institutions ($TINS_i$ from Equations 53 and 54). One of these three variables must be held constant in order for Equation 62 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 63. 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 ($FSAV$). In order 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 64, total savings is the sum of private savings from post-tax disposable income ($MPS_i \cdot \left(1 - TINS_i\right) \cdot YI_i$), 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 65 shows how the saving rates of domestic nongovernment institutions (MPS_i) are composed 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 55, each representative household consumes commodities under a Linear Expenditure System (LES) of demand. This system allows for an income-independent level of consumption ($PQ_c \cdot \gamma_{ch}^m$) 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 55 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 upwards to account for greater consumption demand. This is achieved by increasing the quantity of income-independent demand (γ_{ch}^m) 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 61) are adjusted upwards 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 66 describes the first step at which the average economy-wide rental rate of capital ($AWF^{a}_{f\,t}$) is calculated for time period *t*. This 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 ($\eta^{a}_{f\,a\,t}$) is calculated by comparing its rental rate to the economy-wide average. For those sectors with above average rental rates, the second term on the right-hand side of Equation 67 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 68 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 ($PK_{f\,t}$). This is then multiplied by each sector's share of new capital ($\eta^{a}_{f\,a\,t}$) to arrive at a final quantity allocated to each sector ($\Delta K^{a}_{f\,a\,t}$). The determination of the unit capital price is shown in Equation 69. In the final step the new aggregate quantity of capital ($QFS_{f\,t+1}$) and the sectoral quantities of capital ($QF_{f\,a\,t+1}$) are adjusted from their previous levels to include new additions to the capital stock. Over and above 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^{va}_{a} parameter in Equation

26 by the percentage change in total factor productivity (TFP), or $\delta^{va}_{f\,a}$ 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 57 for government consumption spending, $trnsfr_{i\,gov}$ in Equation 58 for government transfers to households, and $trnsfr_{i\,row}$ in Equation 63 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) is constructed using the survey data, there is a direct mapping between commodities and households in the model and survey. Therefore changes in $QH_{c\,h}$ from Equation 55 (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.

Table A2. CGE Model Sets, Parameters, and Variables

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

Table A2 contd. CGE Model Sets, Parameters, and Variables

Symbol	Explanation	Symbol	Explanation
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		
Endogenous Variables			
AWF_{ft}^a	Average capital rental rate in time period t	QG_c	Government consumption demand for commodity
$DMPS$	Change in domestic institution savings rates (= 0 for base; exogenous variable)	QH_{ch}	Quantity consumed of commodity c by household h
DPI	Producer price index for domestically marketed output	QHA_{ach}	Quantity of household home consumption of commodity c from activity a for household h
EG	Government expenditures	$QINTA_a$	Quantity of aggregate intermediate input
EH_h	Consumption spending for household	$QINT_{ca}$	Quantity of commodity c as intermediate input to activity a
EXR	Exchange rate (LCU per unit of FCU)	$QINV_c$	Quantity of investment demand for commodity
$GSAV$	Government savings	QM_c	Quantity of imports of commodity c
QF_{fa}	Quantity demanded of factor f from activity a		

Table A2 contd. CGE Model Sets, Parameters, and Variables

Symbol	Explanation	Symbol	Explanation
Endogenous Variables Continued			
MPS_i	Marginal propensity to save for domestic nongovernment 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	RWF_f	Real average factor price
PK_{ft}	Unit price of capital in time period t	$TABS$	Total nominal absorption
PM_c	Import price (domestic currency)	$TINS_i$	Direct tax rate for institution i (i ∈ INSDNG)
PQ_c	Composite commodity price	$TRII_{ii'}$	Transfers from institution i' to i (both in the set INSDNG)
PVA_a	Value-added price (factor income per unit of activity)	WF_f	Average price of factor
PX_c	Aggregate producer price for commodity	YF_f	Income of factor f
$PXAC_{ac}$	Producer price of commodity c for activity a	YG	Government revenue
QA_a	Quantity (level) of activity	YI_i	Income of domestic nongovernment institution
QD_c	Quantity sold domestically of domestic output	YIF_{if}	Income to domestic institution i from factor f
QE_c	Quantity of exports	ΔK^{a}_{fat}	Quantity of new capital by activity a for time period t

Table A3. CGE Model Equations

Production and Price Equations	
$QINT_{c\,a} = ica_{c\,a} \cdot QINTA_a$	(23)
$PINTA_a = \sum_{c \in C} PQ_c \cdot ica_{ca}$	(24)
$QVA_a = \alpha_a^{va} \cdot \left(\sum_{f \in F} \delta_{f\,a}^{va} \cdot \left(\alpha_{f\,a}^{vaf} \cdot QF_{f\,a} \right)^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}}$	(25)
$W_f \cdot \overline{WFDIST}_{fa} = PVA_a \cdot (1 - tva_a) \cdot QVA_a \cdot \left(\sum_{f \in F'} \delta_{f\,a}^{va} \cdot \left(\alpha_{f\,a}^{vaf} \cdot QF_{f\,a} \right)^{-\rho_a^{va}} \right)^{-1} \cdot \delta_{f\,a}^{va} \cdot \left(\alpha_{f\,a}^{vaf} \cdot QF_{f\,a} \right)^{-\rho_a^{va} - 1}$	(26)
$QF_{f\,a} = \alpha_{f\,a}^{van} \cdot \left(\sum_{f' \in F} \delta_{f\,f'\,a}^{van} \cdot QF_{f'\,a}^{-\rho_{f\,a}^{van}} \right)^{-\frac{1}{\rho_{f\,a}^{van}}}$	(27)
$W_{f'} \cdot WFDIST_{f'\,a} = W_f \cdot WFDIST_{f\,a} \cdot QF_{f\,a} \cdot \left(\sum_{f'' \in F} \delta_{f\,f''\,a}^{van} \cdot QF_{f''\,a}^{-\rho_{f\,a}^{van}} \right)^{-1} \cdot \delta_{f\,f'\,a}^{van} \cdot QF_{f'\,a}^{-\rho_{f\,a}^{van} - 1}$	(28)
$QVA_a = iva_a \cdot QA_a$	(29)
$QINTA_a = inta_a \cdot QA_a$	(30)
$PA_a \cdot (1 - ta_a) \cdot QA_a = PVA_a \cdot QVA_a + PINTA_a \cdot QINTA_a$	(31)
$QXAC_{a\,c} = \theta_{a\,c} \cdot QA_a$	(32)
$PA_a = \sum_{c \in C} PXAC_{ac} \cdot \theta_{ac}$	(33)
$QX_c = \alpha_c^{ac} \cdot \left(\sum_{a \in A} \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac}} \right)^{-\frac{1}{\rho_c^{ac} - 1}}$	(34)
$PXAC_{a\,c} = PX_c \cdot QX_c \left(\sum_{a \in A'} \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac}} \right)^{-1} \cdot \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac} - 1}$	(35)
$PE_c = pwe_c \cdot EXR - \sum_{c' \in CT} PQ_c \cdot ice_{c'c}$	(36)
$QX_c = \alpha_c^t \cdot \left(\delta_c^t \cdot QE_c^{\rho_c^t} + (1 - \delta_c^t) \cdot QD_c^{\rho_c^t} \right)^{\frac{1}{\rho_c^t}}$	(37)
$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} \cdot \frac{1 - \delta_c^t}{\delta_c^t} \right)^{\frac{1}{\rho_c^t - 1}}$	(38)

$QX_c = QD_c + QE_c$	(39)
$PX_c \cdot QX_c = PDS_c \cdot QD_c + PE_c \cdot QE_c$	(40)
$PDD_c = PDS_c + \sum_{c' \in CT} PQ_{c'} \cdot icd_{c'c}$	(41)
$PM_c = pwm_c \cdot (1 + tm_c) \cdot EXR + \sum_{c' \in CT} PQ_{c'} \cdot icm_{c'c}$	(42)
$QQ_c = \alpha_c^q \cdot \left(\delta_c^q \cdot QM_c^{-\rho_c^q} + (1 - \delta_c^q) \cdot QD_c^{-\rho_c^q} \right)^{-\frac{1}{\rho_c^q}}$	(43)
$\frac{QM_c}{QD_c} = \left(\frac{PDD_c}{PM_c} \cdot \frac{\delta_c^q}{1 - \delta_c^q} \right)^{\frac{1}{1+\rho_c^q}}$	(44)
$QQ_c = QD_c + QM_c$	(45)
$PQ_c \cdot (1 - tq_c) \cdot QQ_c = PDD_c \cdot QD_c + PM_c \cdot QM_c$	(46)
$QT_c = \sum_{c' \in C'} \left(icm_{cc'} \cdot QM_{c'} + ice_{cc'} \cdot QE_{c'} + icd_{cc'} \cdot QD_{c'} \right)$	(47)
$\overline{CPI} = \sum_{c \in C} PQ_c \cdot cwts_c$	(48)
$DPI = \sum_{c \in C} PDS_c \cdot dwts_c$	(49)
Institutional Incomes and Domestic Demand Equations	
$YF_f = \sum_{a \in A} WF_f \cdot \overline{WFDIST}_{fa} \cdot QF_{fa}$	(50)
$YIF_{if} = shif_{if} \cdot \left[YF_f - trnsfr_{row\,f} \cdot EXR \right]$	(51)
$YI_i = \sum_{f \in F} YIF_{if} + \sum_{i' \in INSDNG'} TRII_{ii'} + trnsfr_{i\,gov} \cdot \overline{CPI} + trnsfr_{i\,row} \cdot EXR$	(52)
$TRII_{ii'} = shii_{ii'} \cdot (1 - MPS_{i'}) \cdot (1 - \overline{tins}_{i'}) \cdot YI_{i'}$	(53)
$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{ih} \right) \cdot (1 - MPS_h) \cdot (1 - \overline{tins}_h) \cdot YI_h$	(54)
$PQ_c \cdot QH_{ch} = PQ_c \cdot \gamma_{ch}^m + \beta_{ch}^m \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma_{c'h}^m \right)$	(55)
$QINV_c = IADJ \cdot \overline{qinv}_c$	(56)
$QG_c = \overline{GADJ} \cdot \overline{qg}_c$	(57)
$EG = \sum_{c \in C} PQ_c \cdot QG_c + \sum_{i \in INSDNG} trnsfr_{i\,gov} \cdot \overline{CPI}$	(58)

$$YG = \sum_{i \in INSDNG} \overline{tins}_i \cdot YI_i + \sum_{a \in A} ta_a \cdot PA_a \cdot QA_a + \sum_{c \in CMNR} tm_c \cdot pwm_c \cdot QM_c \cdot EXR + \\ + \sum_{c \in C} tq_c \cdot PQ_c \cdot QQ_c + \sum_{f \in F} YF_{gov\, f} + trnsfr_{gov\, row} \cdot EXR \quad (59)$$

System Constraints and Macroeconomic Closures

$$QQ_c = \sum_{a \in A} QINT_{c\, a} + \sum_{h \in H} QH_{c\, h} + QG_c + QINV_c + qdst_c + QT_c \quad (60)$$

$$\sum_{a \in A} QF_{f\, a} = QFS_f \quad (61)$$

$$YG = EG + GSAV \quad (62)$$

$$\sum_{c \in CMNR} pwm_c \cdot QM_c + \sum_{f \in F} trnsfr_{row\, f} = \sum_{c \in CENR} pwe_c \cdot QE_c + \sum_{i \in INSD} trnsfr_{i\, row} + FSAV \quad (63)$$

$$\sum_{i \in INSDNG} MPS_i \cdot \left(1 - \overline{tins}_i\right) \cdot YI_i + GSAV + EXR \cdot FSAV = \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c \quad (64)$$

$$MPS_i = \overline{mps}_i \cdot \left(1 + MPSADJ\right) \quad (65)$$

Capital Accumulation and Allocation Equations

$$AWF^a_{f\, t} = \sum_a \left[\left(\frac{QF_{f\, a\, t}}{\sum_{a'} QF_{f\, a'\, t}} \right) \cdot WF_{f\, t} \cdot WFDIST_{f\, a\, t} \right] \quad (66)$$

$$\eta^a_{f\, a\, t} = \left(\frac{QF_{f\, a\, t}}{\sum_{a'} QF_{f\, a'\, t}} \right) \cdot \left(\beta^a \cdot \left(\frac{WF_{f,t} \cdot WFDIST_{f\, a\, t}}{AWF^a_{f\, t}} - 1 \right) + 1 \right) \quad (67)$$

$$\Delta K^a_{f\, a\, t} = \eta^a_{f\, a\, t} \cdot \left(\frac{\sum_c PQ_{c\, t} \cdot QINV_{c\, t}}{PK_{f\, t}} \right) \quad (68)$$

$$PK_{f\, t} = \sum_c PQ_{c\, t} \cdot \frac{QINV_{c\, t}}{\sum_{c'} QINV_{c'\, t}} \quad (69)$$

$$QF_{f\, a\, t+1} = QF_{f\, a\, t} \cdot \left(1 + \frac{\Delta K^a_{f\, a\, t}}{QF_{f\, a\, t}} - \upsilon_f \right) \quad (70)$$

$$QFS_{f\, t+1} = QFS_{f\, t} \cdot \left(1 + \frac{\sum_a \Delta K_{f\, a\, t}}{QFS_{f\, t}} - \upsilon_f \right) \quad (71)$$

Table A4. Structure of Poverty and Production in Sub-Saharan Africa (1999)

	Number of countries	GDP p.c. (1995 $US)	Poverty headcount	Share of population or GDP (%) Total population	Poor population	Rural population	Agric. 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
Cote 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

Table A4 contd. Structure of Poverty and Production in Sub-Saharan Africa (1999)

	Number of countries	GDP p.c. (1995 $US)	Poverty headcount	Share of population or GDP (%)				
				Total population	Poor population	Rural population	Agric. to GDP	Industry to GDP
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
C.A. Rep.		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
D.R. Congo		85	92.4	7.9	12.5	60.0	56.3	18.8
Rep. 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: Own calculations using World Development Indicators (World Bank 2003a) and UNIDO (2004) for 1999 dollar-a-day poverty rates.
Note: Simple averages were used thus treating all countries equally regardless of population. Five Sub-Saharan countries are excluded due to data-limitations (Eritrea, Mayotte, Sao Tome and Principe, Seychelles, and Somalia).

Table A5. Growth Decomposition for African Countries (1985-1999)

	Share of GDP (1999)			GDP growth rate (%)			Growth contribution (%)			GDP
	Agric.	Ind.	Serv.	Agric.	Ind.	Serv.	Agric.	Ind.	Serv.	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
Cote 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

Table A5 contd. Growth Decomposition for African Countries (1985-1999)

	Share of GDP (1999)			GDP growth rate (%)			Growth contribution (%)			GDP growth
	Agric.	Ind.	Serv.	Agric.	Ind.	Serv.	Agric.	Ind.	Serv.	
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
C.A. Rep.	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
D.R. Congo	56.3	18.8	24.9	1.1	-6.1	-7.0	0.5	-1.4	-2.4	-3.3
Rep. 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: Own calculations using World Development Indicators (World Bank 2003a).
Note: Aggregations across countries are simple averages rather than GDP weighted averages. Although average GDP shares for 1985-01 were used for decomposition, only the share for 2001 is shown in order to remain consistent with other tables. *Agric.* is agriculture; *Ind.* is industry; and *Serv.* is services.

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