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System of Measurement
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Abbreviations and Acronyms

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This background paper to the Technical Assistance to Public Expenditure Management in Rwanda was prepared by Xinshen Diao, Shenggen Fan, Sam Kanyarukiga and Bingxin Yu, and examines the impact of alternative agriculture investment scenarios on growth in the sector as well for the economy overall. The paper forms part of the background analytical work to inform the TA-PEM which is being provided to the Government of Rwanda by a team consisting of (in alphabetical order): Xinshen Diao, Kossi Eguida, Kene Ezemenari (Task Team Leader), Hippolyte Fofack, Edith Kikoni, Chukwuma Obidegwu, Hannah Sibylle Nielsen, Marinus Verhoeven, Jos Verbeek, Simplice Zouhon-Bi. Logistical support and assistance to the team was provided by Aline Dukuze and Maude Jean-Baptiste. .

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SUMMARY

Agricultural development strategies that are put forward by individual African countries under the Comprehensive Africa Agricultural Development Programme (CAADP) delineate priorities for actions to enhance agricultural and overall development. Understanding alternative agricultural growth options and their linkages with poverty reduction, and prioritizing agricultural investments are the two key components of an agricultural development strategy based on assessments of national needs. However, the relationships between growth and poverty reduction and between targeted growth and required public investment are not straightforward, and solid research is necessary in order to support an evidence-based policymaking process. This report provides such a study using Rwanda as a case. In particular, an economywide model is developed for the study and this model is applied to the most recent economic data and public investment information to analyze agricultural growth and investment options for poverty reduction in Rwanda. The report shows that the country's targeted agricultural subsector growth, if achieved, would allow Rwanda to meet the CAADP target of six percent agricultural GDP growth in the next nine years. With comparable growth in the nonagricultural sector, rapid economic growth would cause the national poverty rate to fall to 35.5 percent by 2015, a reduction of 25 percentage points over the 1999 rate. While the majority of rural households benefit from rapid agricultural growth, the most vulnerable households – those with very small landholdings and with few opportunities to participate in the production of export crops – appear to benefit less. The report shows that economywide growth led by the agricultural sector has a greater poverty reduction effect than the same level of growth driven by the nonagricultural sector. Among agricultural subsectors, growth driven mainly by increased productivity in staple crops has the greatest poverty reduction effect.

The report points out that meeting the CAADP six percent agricultural growth target in Rwanda will require the allocation of public resources to the agricultural sector to rise significantly, and the allocation of 10 percent of total government budget into agricultural spending. Estimated economywide returns to public investment in agriculture are high, and will come not only from growth in the agricultural sector. Through linkage and multiplier effects, one dollar of public investment in agricultural staples generates 3.63 dollars of increased agricultural gross domestic product (GDP) and 0.21 dollar of increased nonagricultural GDP. In the agricultural sector, economywide returns from investing in staple foods, including staple crops and livestock, are much higher than from investing in export crops. However, while the investment returns are high, the planned amount of investment in Rwanda will not be enough to significantly improve the low yield situation for many food crops in the country. The average yield for maize will stay at a low level by 2015 -- a level already reached by many African countries today.

The report also points out the trade-offs between rapid growth and low economywide returns from investing in the export sector. Targeting the export sector through public policy and investment will bring double-digit growth to the sector, measured by an increase in GDP; however, economywide returns to such investment are low. The weak linkages of the export sector with other economic activities on both the supply and demand sides lower the role of the export sector as a key driver in both overall economic growth and poverty reduction. Nevertheless, the export sector has often attracted more government attention among many African countries, with favorable policies and investment support. The findings of this report, which show relatively low economywide returns to public spending in the export sector and relatively less poverty reduction from growth led by promoting exports, further emphasize the importance of broad-based agricultural growth. Agricultural development strategy, including effective public investment strategy, has to focus on growth in which a majority of farmers can participate. Only such a strategy can be expected to be efficient and effective for growth and poverty reduction, as well as for economic development in general.

1. INTRODUCTION

1. Over the last 10 years, Rwanda has made a remarkable transition from genocide to peace and development. Between 1995 and 2006, GDP growth averaged 7.3 percent per year. Financed largely by donor funds, reconstruction efforts have been strong. Public investment has picked up and reached an estimated 6.8 percent of GDP in 2004. Private investment has increased as well, rising to an estimated 12.8 percent of GDP in recent years. Significant progress has also been made in improving health and education indicators.

2. Despite this impressive progress, severe challenges remain. The destruction of human and physical capital that ensued from the genocide severely reduced productivity, household income, and government revenue, leading to an increase in poverty. Rwanda remains very poor, with a per-capita annual income of US$ 260, and about 60 percent of the population lives on less than US$ 1 per day. Growth has moderated over the last few years as the post-conflict economic recovery comes to an end. If Rwanda is to meet its target of reducing its poverty rate by one-half and achieving the Millennium Development Goals (MDGs) by 2015 or 2020, economic growth must increase significantly.

3. The Rwandan government's strategy for reducing poverty and stimulating rapid and sustainable economic growth is laid out in the first Poverty Reduction Strategy paper (PRSP) and is further articulated in the government document Vision 2020. Agricultural transformation figures prominently in both documents. According to Vision 2020, agricultural transformation is expected to boost off-farm growth in both the formal and informal sectors, with the effect of reducing the proportion of the population dependant on agriculture from the present 87 percent to about 50 percent in 2020. In addition, because agricultural productivity is currently very low, there is considerable potential to achieve rapid income gains by increasing productivity in the short run. In the more recent second PRSP, the Economic Development and Poverty Reduction Strategy (EDPRS), the focus on agriculture and infrastructure has been further strengthened, and the distributional effect of growth is seen to matter more with growth over time (MINECOFIN, 2007).

4. Agriculture features prominently in the Rwandan economy, and currently accounts for 40 percent of GDP. Agricultural commodities, mainly tea and coffee, generate 70 to90 percent of total export revenues. Modest production gains achieved in recent years in the coffee and tea sectors have allowed Rwanda to broaden its revenue base, but the value per capita of commodity exports remains much lower than the average value for Sub-Saharan Africa as a whole. In addition, the overall performance of Rwanda's agricultural sector in recent years has been disappointing. Productivity in many staple crops and livestock sector has remained flat, while average farm sizes have declined, leaving many farmers' incomes lower than they were during the pre-genocide period. Marketable surpluses have declined, compounding the problem of production being consumed mainly on the farm. With less and less product sold in local markets, the amount of income available to support the non-farm rural sector has fallen. Because Rwanda's economy is heavily dependent on agriculture, the key to poverty reduction lies in stimulating rapid and sustainable growth in the agricultural sector.

5. The role of agriculture in growth and poverty reduction has been broadly discussed, in particular for low income African countries (see, for example, Diao et al. (2007) for a synthetic review of economic literature). Moreover, the recent world food price crisis further enhances the urgent need to significantly improve African countries' agricultural performance. A recent World Bank study suggests that the surge in prices could plunge many Africans into poverty (Ivanic and Martin, 2008), while the effects of food-induced inflation and deteriorating trade deficits on economic growth will only be felt in the years to come. Several studies have also suggested that, unlike the 1974 food crisis, the current crisis may be characterized by higher real food prices for many years in the future (OECD-FAO, 2007; USDA, 2008;

von Braun, 2007). In the face of surging food prices, it is especially critical to focus on revitalizing the agricultural sector in African countries, for several reasons. In addition to its immediate impact on food security, agriculture is still the largest source of employment for African countries, including Rwanda, and it remains a lead sector of comparative advantage (Diao and Dorosh, 2007). Moreover, agricultural productivity growth has repeatedly been shown to be the primary driver of global poverty reduction (Christiansen et al, 2006; Thirtle et al. 2003; Byerlee et al. 2005; Bezemer and Headey 2008), both through its direct effects on farmers' incomes, as well as its indirect effect through the reduction of food prices. The sector also has tremendous growth potential when the right policies are in place. Faster agricultural growth has put countries on the path of a much broader transformation process: rising farm incomes raise demand for industrial goods; lowered food prices curb inflation, and induced non-farm growth increases the demand for unskilled workers. Rising on-farm productivity also encourages broad entrepreneurial activities through diversification into new products, the growth of rural service sectors, the birth of agro-processing industries, and the exploration of new export markets (World Bank, 2008).

6. Against this background, this study will assess the likely effectiveness of alternative agricultural development strategies for stimulating growth and poverty reduction in Rwanda. We expect that this report will provide knowledge-based evidence to support the efforts of the Government of Rwanda to identify areas in which policy reforms supported by public and private investment can best help advance the national agricultural development agenda. Three policy-related questions are the focus of this study: (1) What are the most effective pro-poor agricultural growth strategies? (2) How can the important linkages between agriculture and nonagriculture be strengthened such that non-farm activities will become an important source of income for both growth and poverty reduction? (3) What are the most cost effective public investment choices for stimulating shared growth and poverty reduction? In Chapter Two of this report, we first introduce the analytic tools and data used for this study. Chapter Three briefly discusses the structure of Rwandan agriculture and rural economy. Chapter Four presents the model results from a "business as usual" scenario. Chapter Five analyzes the agricultural subsectoral contribution to both income growth and poverty reduction. Chapter Six assesses the public investment in agriculture required to achieve CAADP and poverty reduction goals. Chapter Seven concludes the report with major findings that are highly policy-relevant in agricultural development strategy issues.

2. ANALYTIC TOOLS AND DATA

A. DEVELOPING A DYNAMIC GENERAL EQUILIBRIUM MODEL FOR THE STUDY

7. An economywide model is the proper tool for analyzing agricultural growth and investment options, as such a model captures synergies and trade-offs from accelerating growth in alternative agricultural subsectors and the economic inter-linkages between agriculture and the rest of the economy in Rwanda. For this reason, we have developed a dynamic general equilibrium (DCGE) model for this study. A static, standard CGE model was developed in the early 2000s at the International Food Policy Research Institute (IFPRI) and has been documented in Lofgren (2000). The recursive dynamic version of the CGE model is based on this standard CGE model with the incorporation of a series of dynamic factors. The early version of this dynamic CGE model can be found in Thurlow (2004), while its recent applications include two country case studies, Zambia and Uganda, in Diao et al. (2007).

8. Similar to other CGE models, our DCGE model is an economywide, multi-sectoral model that solves simultaneously and endogenously for a series of economic variables including commodity and factor prices. However, unlike traditional CGE models that focus on national economies with multiple production sectors, our DCGE model considers subnational heterogeneity in agricultural production by assigning a series of different production functions for producing a similar agricultural product, e.g., maize or cassava, to different regions or districts and different types of farms. The setup of such a model

requires more information about a country's agricultural production than a traditional CGE model; for instance, information about the distribution of land across regions or districts and types of farms for each individual type of crop or livestock production, which significantly increases the complexity of calibrating the model to the real economy. However, once such information is available and the model is constructed according to it, the model can better capture the economic inter-linkages at both subnational and national levels, including both inter-linkages across regions and those between sectors. The specific subnational structure of the agricultural production of the model will be further discussed in detail later when we introduce the dataset, the Rwanda social accounting matrix (SAM), and agricultural structure in the next chapter.

9. Like any other CGE model, the DCGE model captures, with its general equilibrium feature, economic activities on both the supply and demand sides. On the supply side, the model has defined specific production functions for each economic activity, such as agricultural production, for which the functions are defined at the subnational level, or non-agricultural production, which is defined at the national level. As in any other quantitative economic analysis, certain assumptions have to be applied before calibrating the model to the data. In a typical CGE model, a constant return to scale technology with constant elasticity of substitution (CES) between primary inputs is a fundamentally necessary assumption in order for the model to have a general equilibrium solution. However, as both primary and intermediate inputs are considered in the production functions of a CGE model, a Leontief technology with fixed input-output coefficients is often assumed for the use of intermediate inputs, such as fertilizer and seeds in crop production, feed in animal production, and raw materials in the food processing industry, as well as for the relationship between intermediates and primary inputs in aggregation.

10. The demand side of the CGE model is dominated by a series of consumer demand functions. In our model, the system of consumer demand functions is solved from maximizing a Stone-Geary utility function in which the income elasticity is not necessarily one (which differs from a Cobb-Douglas utility function), and hence, the marginal budget share for each consumer good departs from the average budget share of this good in consumers' total budget.[1] With such a utility function assumed, information on income elasticity is required in order to calibrate the demand system to the data. We will discuss this in detail later in the discussion about the data and other parameters applied in the model. As in any other general equilibrium model, consumers' income that enters the demand system is an endogenous variable. Income generated from the primary factors employed in the production process is the dominant income source for consumers, while incomes coming from abroad (as remittance received) or the government (as direct transfers) are also considered.

11. The relationship between supply and demand has to be explicitly modeled in a CGE model, and determines the equilibrium prices in the domestic markets. Given that a CGE model also captures the trade flows --both import and export--the relationship between domestic and international markets is also modeled explicitly. Generally speaking, any commodity produced or consumed in the domestic market can also be an exported or imported one. However, in a CGE model, the commodities produced or consumed in the domestic market are not perfectly substitutable for those going to or coming from international markets. Because of this assumption, the international price for any product, regardless of whether this product is exportable or importable, cannot be fully transmitted into domestic markets, and

[1] Marginal budget share (MBS) relates the allocation of incremental income spent on different consumption goods for a consumer, while average budget share (ABS) is the current (total) budget allocation among different goods. For example, a consumer currently spends 2 percent of her (his) income on rice consumption, indicating that the ABS for rice is 2 percent. When this consumer's income increases in the next year, for each increased one dollar of income, she (he) prefers to spend 3 cents on rice. In this case, the value of MBS for rice is 3 percent. When MBS is greater than ABS for a particular consumption good (in this case, rice), demand for this good is called income elastic. On the other hand, if MBS value is lower than ABS for a particular good, e.g., sorghum, demand for this good (sorghum) is said income inelastic. The relationship between MBS and ABS will be further discussed in Chapter 3.

changes in domestic supply and demand will finally determine its price. However, if a product is exportable or importable, its price in domestic markets can be affected by international prices and by the export and import demands. To capture such linkages with international markets, the model assumes price-sensitive substitution (imperfect substitution) between foreign goods and domestic production. With such an assumption, if domestic demand increases more than the supply of this good, the domestic price for this good raises relative to the export/import prices. Exports of this good fall and imports rise. On the other hand, if productivity improves in the domestic production and rising supply outpaces the increases in demand for the product, domestic price then falls relative to the border prices, exports rise and imports fall. Imperfect substitution also implies that agricultural productivity improvement by itself may not be enough to expand agricultural exports, and improving marketing conditions is also necessary.

12. While the linkages between demand and supply through changes in income (an endogenous variable) and productivity (often an exogenous variable) are the most important general equilibrium interactions in an economywide model, production linkages also occur across sectors through intermediate demand and competition for primary factors employed in production sectors. Many primary agricultural products need to be processed before reaching consumers and export markets. Food processing is often an important component of the manufacturing sector in developing countries. Productivity-led growth in the agricultural sector can stimulate growth in food processing by providing cheap inputs (forward linkages) and creating more demand for processed goods (backward linkages through rising income of farmers). On the other hand, growth in an export-oriented agricultural product, e.g., coffee or tea in Rwanda, often creates increased demand for processing coffee and tea. Although most of such processing activities create a small amount of value addition, they increase labor demand, and hence create job opportunities for both rural and urban households. Obviously, without a general equilibrium framework and detailed subsector structure in both agriculture and non-agriculture, it is unlikely to capture such economywide impact of agricultural growth in an analysis.

13. Investments affect production over time and productivity growth is a gradual process. Capturing this dynamic process is a key component of our DCGE model. Given the complexity of the model setup for Rwanda, measured both in the large number of production sectors in agriculture and non-agriculture, and the disaggregated agricultural production and household groups across subnational regions, it is unrealistic to expect a fully developed intertemporal general equilibrium model for this study.[2] Thus, recursive dynamics are applied in the model. With such a model setup, the dynamics occur only between two periods and neither consumption smoothing along the growth path not the intertemporal investment nor saving decisions are taken into account. Instead, private investment (hence capital accumulation) are determined by a Solow type of saving decision in which savings are proportional to income and not endogenously solved from a Ramsey type of intertemporal utility function.[3] While population growth, land expansion at the subnational and national level, and productivity growth are all exogenously determined, productivity growth in the agricultural sector can be endogenously linked with public investments. In Chapter Five of the report, we will link public spending and its allocation to productivity growth in the agricultural sector to assess the returns to agricultural investment.

14. The government is generally included in a CGE model as an institutional account. In our model, the government collects taxes (including tax revenue from domestic households and producers, export taxes, and import tariffs), transfers part of this income to households, and uses the rest either as investments or recurrent spending. As in many other Sub-Saharan African countries, a major part of government spending in Rwanda is financed by international or developed country donors. In the model it is captured as a transfer to the government coming from abroad. The required government spending to

[2] An intertemporal general equilibrium model in literature is often used with a relatively aggregated economic structure. See Diao et al. (2005) for the growth linkage analysis in the case of Thailand.

[3] See Diao et al. (1998) for the discussion of Ramsey type intertemporal utility function and its role in determination of consumers' consumption and saving behaviors.

support agricultural growth will be calculated in Chapter Five. Increased government spending can have a certain general equilibrium effect (indirect effect) as it creates more demand for investment goods or services produced domestically (e.g., construction services) or imported (capital goods). Change in government demand due to increased public investment affects the prices in domestic markets for both commodities and factors. However, given that the public spending to finance public investment is primarily from the international community, we have decided to ignore this more complicated general equilibrium effect in the study. Moreover, including it in the model will not significantly change the results of the study. Mathematical presentation of the DCGE model of Rwanda can be found in the Appendix II.

B. Microsimulation Model and Poverty Analysis

15. While the impact of agricultural growth on the poor can be partially captured directly by the DCGE model simulations, assessing the impact of growth on headcount poverty reduction depends on data that fully capture the poverty distribution of the country. For this reason, a simple microsimulation model was created, based on the 2005–2006 Enquete Integrale Sur les Conditions de Vie des Menages au Rwanda (EICV2, or Household Living Conditions Survey), the most recent national living standard survey in the country (MINECOFIN 2007). Specifically, the commodity expenditure of each sample household in the microsimulation model is defined consistently with the sectors and commodities defined in the DCGE model. Changes in consumption spending at the sample household level are calculated according to the results from the DCGE model simulations. As in the DCGE model, the representative households are aggregated from the survey data, and each sample household in the microsimulation model can be traced to its representative household. With such macro-to-micro linkage setup, the poverty rate at national, rural and urban levels can be recalculated in a way consistent with the changes in income and consumption patterns endogenously generated from the DCGE model.

C. Constructing a Highly Disaggregated Social Accounting Matrix

16. The key dataset used in any CGE modeling analysis is called a social accounting matrix (SAM). The 2006 SAM of Rwanda was constructed by Arnault Emini (2007) under a joint project between the Ministry of Economy and Finance (MINECOFIN) in collaboration with the Ministry of Agriculture (MINAGRI) and the World Bank. The main part of the SAM construction work was undertaken in Kigali by Arnault Emini, with close interaction with staff from MINECOFIN, MINAGRI and other government institutions, including the Rwanda Revenue Authority (RRA), the National Bank of Rwanda (NBR) and the National Institute of Statistics of Rwanda (NISR). This SAM was constructed for the national economy, and 51 agricultural and nonagricultural sectors are defined at the national level, with two primary factors – labor and capital–as inputs.

17. For the purpose of this study, this SAM has to be further disaggregated. Specifically, we have to separate land from capital account in the national SAM and disaggregate the original sector of "bakery, processed coffee, tea and sugar" into three subsectors: processing coffee, processing tea, and other food processing. Further SAM disaggregation includes: (1) disaggregating agricultural crop production into 30 districts and within each district into two types of farm groups, small farm and medium and large farm groups; (2) disaggregating livestock production into 30 districts; and (3) defining rural households at the district level for small farmer and medium and large farmer groups, while defining urban households as urban Kigali (the capital) and other urban.

18. The SAM disaggregation is motivated by the need to better capture heterogeneity in production structure across districts, and source of income across different types of farm groups. While a majority of Rwandan farmers are involved in staple crop and livestock production, the opportunities to participate in high value crop production are not equally distributed among them. For example, tea, one of the most

important export crops of the country, is only produced in 10 of the 30 districts, mainly in the West Province. Moreover, tea is produced by large farmers, though small farmers can participate as labor providers. In the case of coffee, the other important export crop of the country, while 19 districts have coffee production, the main production area concentrates in Southern and West Provinces. With such uneven distribution in export crop production opportunities, if public support concentrated in promoting tea and coffee production and exports, the benefits of such a policy would not be likely to reach those farmers outside tea and coffee growing areas. Without a disaggregated SAM, and hence a disaggregated CGE model, such uneven distribution in the income gains from tea and coffee promotion policies will be ignored, as well as the impact on poverty reduction of such policy.

19. The disaggregation of the SAM is based on the information drawn from EICV2 and Rwanda Agricultural Survey 2006 (MINECOFIN 2007). The economic structure of the country with such disaggregation will be discussed in the next chapter. After the disaggregation, on the production side, there are 960 production activities for 16 crop sectors (16 sectors x 30 districts x 2 types of farms = 960); and 270 production activities for 9 livestock sectors (9 x 30 = 270); and 28 nonagricultural sectors defined at the national level. On the demand side, there are 63 representative household groups: 60 (30 districts x 2 types of farm households = 60) in the rural area and 2 in the urban area.

D. Parameters and Elasticities Applied in the DCGE Model

20. Any analysis based on a model with a system of equations depends critically on the elasticities and parameters employed in the model. However, unlike most partial equilibrium models, in which supply and demand functions are constructed as elasticity-based functions, in a CGE model, well behaved structural functions are employed that are solved from maximizing profits on the producer side and maximizing welfare on the consumer side.. In this way, the parameters capturing the economic structure and factor intensity at the sector level (in our case at sector and district level) play more important roles in determining the model results than elasticities do. All these parameters have to calibrate to the data, together with the predetermined elasticities.

21. Specifically, the substitution elasticity between primary inputs in the constant elasticity of substitution (CES) production function has to be assumed or chosen from the literature, as any country's dataset used to construct a CGE model is generally unable to support an econometric estimation for obtaining such elasticity for the entire production system included in the model. For example, if a Cobb-Douglas (CD) technology is chosen as the production structure of a CGE model, it then implicitly assumes a unit elasticity of substitution between primary inputs (e.g., labor, land, and capital) in the production functions. In this way, other parameters in the CD production function of the model (e.g., the marginal product of each input and the key parameter in this type of function) can be directly calibrated using the country data of the SAM (i.e., the share of value-added for each input employed in the total value-added of this sector). In our DCGE model, we chose a general CES function form (other than CD technology) to calibrate other parameters in the production function. The elasticity in the production function is pre-determined and drawn from CGE literature about other African countries. The other parameters in the production functions of the model are then calibrated using the data composed in the Rwanda SAM. Also, we decided to use a similar substitution elasticity in the production functions for each production sector across districts and types of farms. However, because of the difference in factor intensity between different types of farms and different sectoral structures across districts, heterogeneity in technology for producing a similar product is captured by calibrating the other parameters of the production function to such disaggregated data.

22. Besides primary inputs, intermediates are also employed in the production process. With the assumption of Leontief technology in the use of intermediates, there are a set of fixed input-output

coefficients applied in the production function, which are directly calibrated using the data of the Rwanda SAM.

23. With a Stone-Geary type of utility function applied in the model, the marginal budget share (MBS) is the parameter applied in the demand system of the model. While the average budget share (ABS) for each individual commodity consumed by each individual household group can be directly calculated using the data of the Rwanda SAM, to derive a series of MBSs the income elasticity of demand has to be obtained.[4] For this study, the income elasticity is estimated from a semi-log inverse function suggested by King and Byerlee (1978) and based on the data of EVIC2 (2005-06). The estimated results as marginal budget shares for different commodities and different groups of households are reported in Appendix I.

E. LIMITATIONS OF THE DCGE MODEL

24. Like any other economic model, the CGE model has its limitations. Of these, there are at least four limitations or caveats that are important to note when interpreting the results. The first caveat is on the demand side. While income elasticities of demand in the model are econometrically estimated and subsistence consumption is taken into account in the demand functions, the use of a linear expenditure system (LES) to specify household demand can only partially capture demand dynamics. Marginal budget shares, and hence the income elasticity in such a demand system, remain constant over time. While rapid demand shifts can be better captured by using an AIDADS demand system (Yu et al., 2003) or by applying latent separability (Gohin, 2005), the highly disaggregated demand structure in the model constrains our choice of methods. Second, similar to most other CGE models, production technologies that are calibrated to the initial economic structure remain constant over time. Because of this, the model simulations do not capture the effects of substantial technological changes and innovations that are embodied in new investments, especially foreign direct investments. Third, the expansion of manufacturing can generate many externalities and spillovers, and the social value of new investments can greatly exceed their private value. As such, the model does not capture increasing returns to scale and technological externalities and spillovers, and may therefore underestimate the contribution of growth in non-traditional and import-substitutable agriculture and the contribution of new manufacturing activities to structural change during a rapid growth period. To address some of these caveats, we run several sensitivity tests, whose results are reported in Appendix III.

25. Bearing these caveats in mind, the CGE model can still provide useful simulations to assess the effects of a particular growth strategy within the context of a broader economic aspect. Thus, with all the parameters and data of the Rwanda SAM discussed above, the DCGE model is ready to conduct simulation analysis. However, before we discuss the simulations and their results for this study, it is necessary to review the structure of the economy, particularly the agricultural side of the economy, in order to properly understand the model results.

3. STRUCTURE OF AGRICULTURE AND RURAL ECONOMY

26. Agriculture is the most important sector in the economy of Rwanda in terms of contribution to GDP, employment, and foreign exchange earnings. According to the national account, the agricultural sector currently accounts for 44 percent of GDP, similar to the calculations from the Rwanda SAM used in this study (see Table A1 in Appendix I for the detailed economic structure in the SAM). However, this figure is likely underestimated, because it is generally difficult to measure exactly the large amount of food that is produced and consumed by farmers at home. In 2005 to 2006, approximately 90 percent of

[4] The ratio of MBS over ABS equals the income elasticity of the demand.

the economically active population was employed in agriculture. However, since as many family members work on their own land, and their income, particularly for small farmers, is primarily embodied in the land they own and farm, the calculated labor income from agricultural production as a share of national total labor income is quite low in the SAM, accounting for about 30 percent of total national labor income. While exports from the primary agricultural sector are small, agricultural exports through processing are large, dominated by tea and coffee exports that account for 31 and 34 percent of national total exports, respectively. In this chapter we will briefly discuss some key characteristics of the Rwandan agricultural economy at both national and subnational levels.

A. DOMESTIC MARKET ORIENTED AGRICULTURE

27. As a land-locked country with poorly developed roads and other infrastructure both in the country and in neighboring countries, Rwandan agriculture is characterized as a sector with few export opportunities besides the two traditional export crops, tea and coffee. Approximately 1.4 million rural households depend on agriculture as their main livelihood source, and almost two-thirds of their products are destined for their own home consumption. According to recent trade data, and also captured in the Rwanda SAM, there are only a very few crops other than tea and coffee in which exports are observed. Moreover, for those exported crops, the value exports are tiny when compared toproduction. One of the most important export crops other than tea and coffee is pyrethrum. However, as the size of this sector is very small and constrained by the availability of production data, pyrethrum is aggregated into a subsector called "other export crop group" in the SAM. Exports account for about 4.1 percent of this subsector's output (Table A1(a) in Appendix I). Other nontraditional exports include vegetables and fruits, but the share of exports in total production is also small, 0.62 percent for vegetables and 0.15 percent for fruits. According to Fowler et al (2007), some staple crops have comparative advantage in regional trade. Regional-export oriented crops include Irish potato, rice, wheat, maize and soybean. Without information on cross border informal trade, the SAM captures only a very small portion of such trade in Irish potatoes and bananas, accounting for 0.40 percent and 0.01 percent of potato and banana production, respectively, in the country (Table A1(a) in Appendix I). Rwanda does export some livestock products, but the share of such exports in total livestock production is also very small (3.2 percent). Such exports are identified as exports of "other livestock," meat other than cattle, sheep and goats, swine and poultry (Table A1(a) in Appendix I). Lack of market access opportunities for exports will become a constraint when growth in agriculture is accelerated. This situation will be further analyzed in the model simulation analysis. Table 1 reports a list of agricultural commodities and their trade situation in the SAM and the DCGE model.

Table 1: Agricultural Commodities in the SAM and DCGE Model

Commodity	Whether exports	Whether imports
Grains		
Maize	No	Yes
Rice	No	Yes
Sorghum	No	No
Wheat	No	Yes
Roots and tubers		
Cassava	No	No
Potatoes	Yes	No
Sweet potatoes	No	No
Other root crops	No	No
Other crops		
Bananas	Yes	No
Pulses	No	No
Oilseed crops	No	No
Vegetables	Yes	No
Fruits	Yes	No
Export crops		
Coffee beans*	No	No
Green tea*	No	No
Other export crops	Yes	Yes
Livestock products		
Beef	No	No
Goat and sheep meats	No	No
Poultry	No	No
Other meat	Yes	No
Fish	No	No
Eggs	No	No
Milk	No	No

* Coffee and tea are exported through their processing sectors defined in Rwanda SAM.
Source: Rwanda SAM

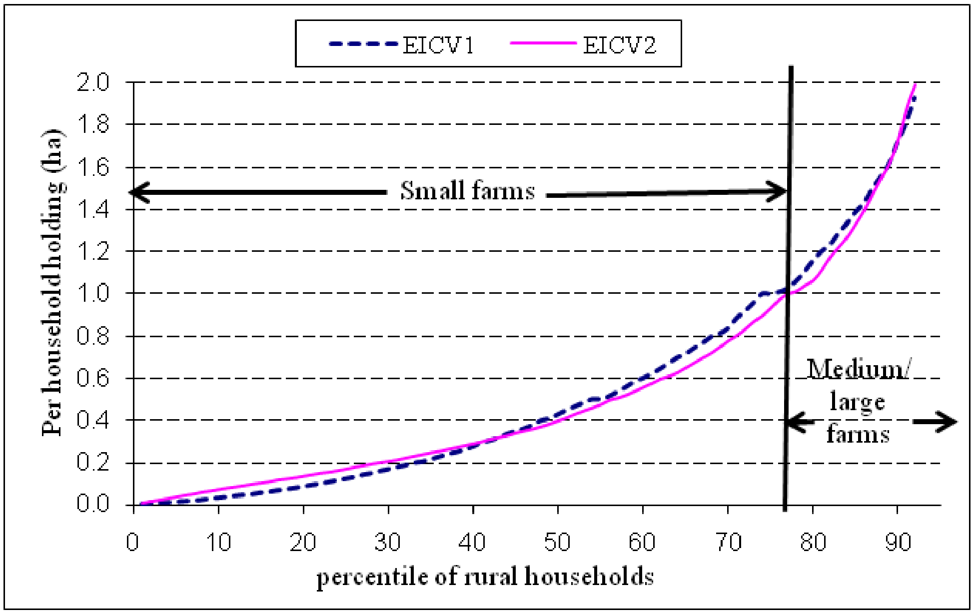
28. While about 90 percent of the economically active population has been engaged in agricultural activities, some food products depend on imports to meet domestic demand in Rwanda. Currently, imports of wheat, maize and rice account for 20 to 36 percent of domestic consumption (Table A1(a) in Appendix I). During the urbanization process, and with population and per capita income growth, imports of these grain products, which are often income-elastic in the early stage of development, are expected to further increase if domestic production cannot catch up with the growth in demand for them. The model simulation analysis will address this issue in the following of the report.

B. Land-Constrained Agriculture Dominated by Rural Households with Extremely Small Landholding Size

29. Rwanda has the highest population density in Africa, rising from 183 per sq km in 1981 to 345 per sq km in 2000. Rural population per square kilometer of arable land is also one of the highest in Africa (ISS 2008). Calculated from the two rounds of national household living condition surveys

(EICV1, 1999-2001 and EICV2, 2005-2006), the total agricultural land handholding in Rwanda is about 1.1 to 1.4 million hectares (ha), average rural households' landholding is 0.75 ha and per capita landholding is 0.15 ha.

Figure 1: Distribution of Rural Household According to Holding Size

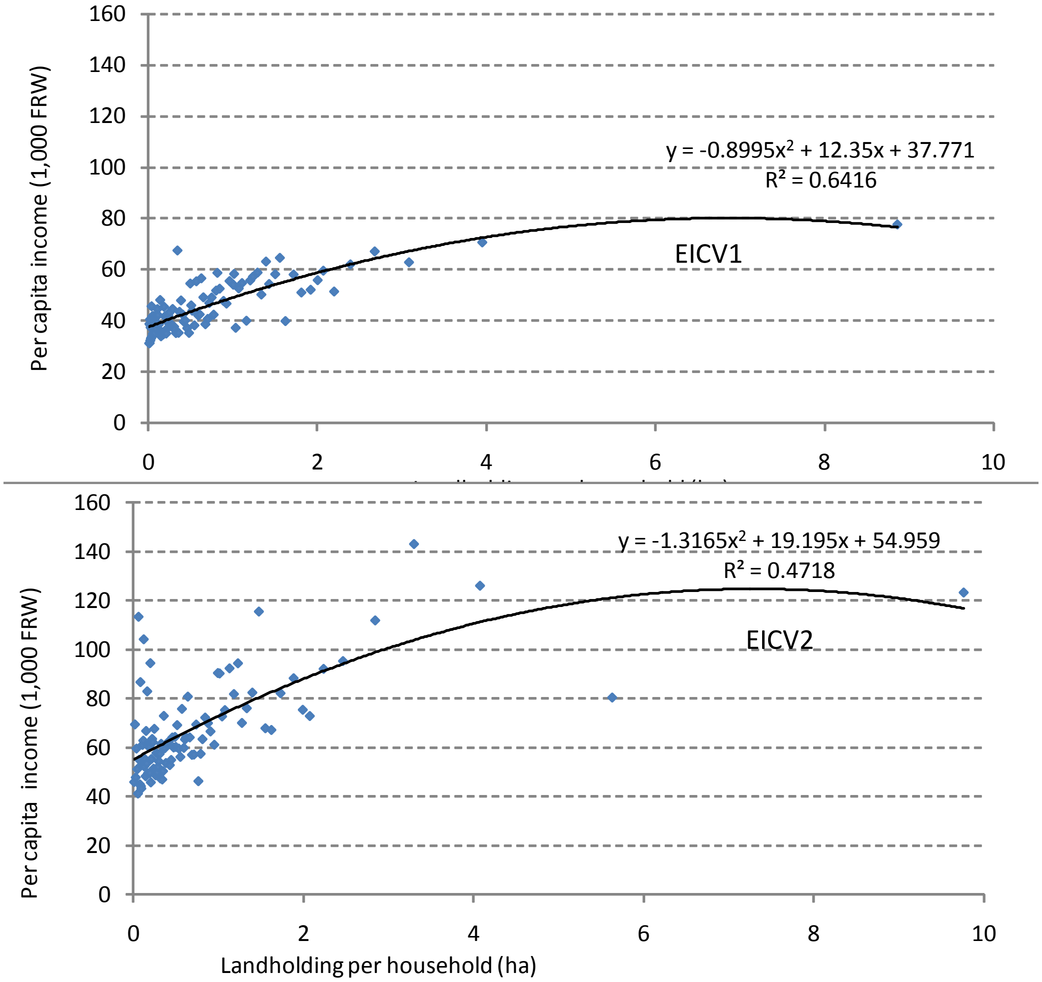


Source: Authors' calculation based on EICV1 (1999-2001) and EICV2 (2005/06) data

30. With such a small amount of average land, small farmers with extremely small land size are expected to dominate the agricultural economy. As shown in Figure 1, even excluding landless rural households, 77 percent of rural households have less than one hectare per household. All these households together own one-third of total agricultural land in the country, with an average household holding size of 0.37 ha.

31. Limited access to land is a key indicator explaining income inequality and poverty in a country such as Rwanda, in which the dominant source of income in the rural area is from the agricultural sector. To capture the correlation between household incomes and landholding size, we run a regression to formalize this relationship by using a quadratic function form. As shown in Figure 2, there is strong correlation between the size of landholding and household income; but the relationship is not linear. The x axis of Figure 2 represents the average size of landholding for each percentile of rural households, ranking from low to high, while the y axis represents average annual income per capita for the same percentile of households (in 1,000 Frw). The R^2 of the regression is 0.64 using data from EICV1 (1999-2001) and 0.47 using EICV2 (2005-2006).

Figure 2: Correlation between Landholding and Household Income



Source: Estimated based on EICV1 (1999-2001) and EICV2 (2005/06) data. Income of EICV2 is deflated to EICV1's.

32. Based on the two household surveys in 1999-2001 and 2005-2006, we see that while 65 and 61 percent, respectively, of rural households in the country have, on average, less than one hectare of land, 77 and 73 percent respectively of the national poor people are from these households (see Table 2). The 1999-2001 national poverty rate was 60.3 percent, 71.1 percent among small farmers and 51.4 percent among other rural households with more than one hectare of land. The 2005-2006 national poverty rate was calculated at 56.9 percent with the poverty rate remaining highest for small farmers, at 68.2 percent, and 46.7 percent for other rural households with more than one hectare of land. These results indicate the importance of productivity-led agricultural growth in poverty reduction in the country. In the modeling simulation, we will further address this issue.

Table 2: Distribution of Population and the Poor

	With land less than one ha	Rural with land more than one ha	Rural total	Urban	National
EICV 1					
Share of population	65.0	24.6	89.5	10.5	100.0
Share of poor population	76.6	20.9	97.5	2.5	100.0
Poverty rate	71.1	51.4	65.7	14.3	60.3
EICV 2					
Share of population	61.1	22.3	83.4	16.6	100.0
Share of poor population	73.3	18.3	91.6	8.4	100.0
Poverty rate	68.2	46.7	62.5	28.7	56.9

Source: Authors' calculation based on EICV1 (1999-2001) and EICV2 (2005/06) data

C. Food-Dominated Consumption Patterns

33. With a low income level for the majority of households, food dominates household consumption expenditure, particularly in the rural areas of Rwanda. As shown in Tables A1-A2 in Appendix I, an average Rwandan rural household spent 77 percent of income on food consumption in early 2000s (EICV1, 1999-2001) and 68 percent in recent years (EICV2, 2005-2006), while food accounted for 47 and 43 percent of total consumption spending for an average urban household in these two time periods. Tables A1 and A2 also report the consumption patterns of different income groups in both rural and urban areas. We aggregate rural and urban households into 10 groups, five in the rural area and five in the urban area, according to per capita income and national population quintiles. Not surprisingly, food consumption accounts for a much higher share of total spending among poor households, those in the first two quintiles, in both rural and urban areas. For example, the poorest 20 percent of rural households must spend 86 percent of their income on food, while for the poorest 20 percent of urban households the food share of total spending is 65 percent.

34. It must also be noted that between these two time periods, the average rural household's income (measured by total expenditure) doubled in real terms, rising from 46,000 Frw per capita in 1999-2001 (Table A1) to 90,000 Frw in 2005-06 (Table A2, with the numbers deflated to be comparable with that in the early period) For urban households, per capita income rose by 40 percent between these two periods. With such significant increases in income, particularly income for rural households, the share of total food consumption only declined modestly. This situation indicates the importance of agricultural development in the country and further justifies the need to increase investment in agriculture to stimulate its growth. The following chapters will analyze it by a series of model simulations.

35. In order to promote more targeted agricultural growth in a domestic market oriented agricultural economy such as Rwanda, it is important to understand whether there exist demand side constraints among different domestic market commodities. For this reason, we further look into the dynamics in household demand by estimating the marginal propensity of income and calculating the marginal budget shares (MBS) of food commodities based on such estimation. In contrast to the average budget share (ABS), which is the share of total current income actually spent on each commodity, and can be directly

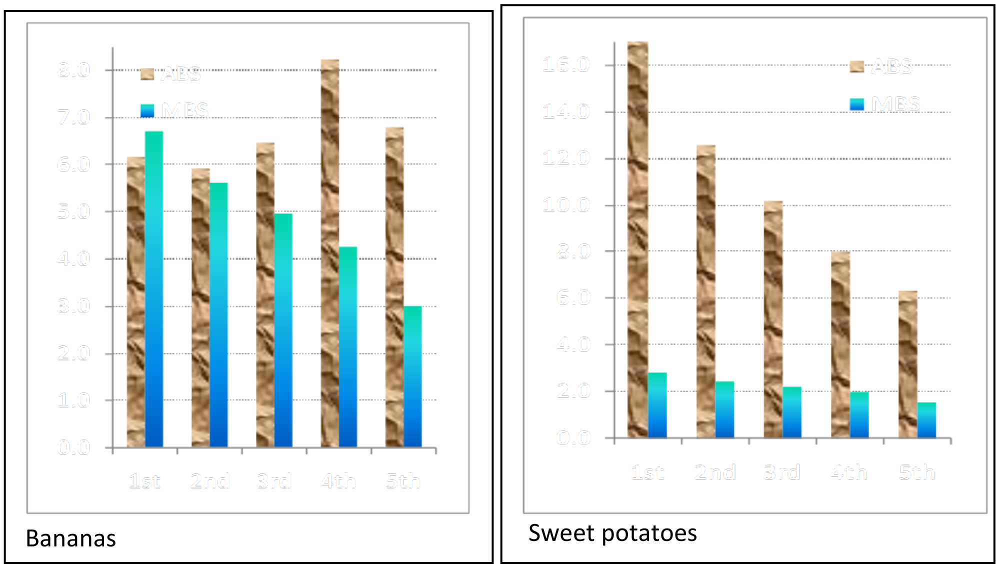
obtained from the calculation of the survey data; the MBS refers to the spending patterns of each additional unit of income. Comparing MBS with ABS can increase our understanding of which commodities households would likely prefer to consume, as their income increases.

36. The MBS needs to be econometrically estimated using complete household survey data. In this study, a semi-log inverse function (RSLI), suggested by King and Byerlee (1978), was used to estimate the marginal propensity to income. To assess the patterns of marginal demand among different income groups in the rural and urban areas, we report MBS for each major food commodity by five income groups in the rural and urban areas according to national population quintiles. The following discussion focuses on the estimated results from the most recent survey (EICV2). Not surprisingly, given that food is the dominant consumption item in household budgets, the MBS of food items in total only declines slightly, from the ABS of 59.3 percent to the MBS of 56.7 percent for the country as whole. That is to say, for each increased 100 Frw of income, an average Rwandan would spend additional 56.7 Frw on food and the rest on other kinds of consumption.

37. While food will continuously be the most important spending item for an increased household income, the MBS can be quite different for different types of food. For example, the MBS for root crops and bananas combined is 37 percent for rural households compared with a value of 40 percent for the ABS of them. Among different staples, households generally spend more increased income on rice, maize, bananas and potatoes, and less on cassava and sweet potatoes. In general, with increased income, households would spend more on high value products such as vegetables, fruits, oil crops, livestock, and processed food. However, while income elasticity for high value food products is high, staples are still dominant food items, even for households with increased income. For example, staple food together accounts for almost 40 percent of each 100 Frw of increased income, while all high value foods account for only 21 percent. To further illustrate the variation of marginal budget spending among different food items, we use two commodities that have a relatively large average budget share for rural households: bananas and sweet potatoes.

38. As individual commodities, bananas and sweet potatoes are important staples for rural households, accounting for 6.9 and 9.2 percent of total spending, respectively, for an average rural household. On the other hand, poor rural households consume more sweet potatoes, and their share in total spending can be as high as 17.3 percent for the poorest 20 percent of rural households. However, estimated marginal budget shares show a quite different pattern between these two commodities. While their MBS is smaller than their ABS for the rural households as whole, the decline in the MBS is much more significant in sweet potatoes than in bananas. The MBS declines to 2.2 percent from 9.2 percent of ABS in the case of sweet potatoes, while the MBS is 5.0 percent compared with 6.9 percent of ABS in the case of bananas. Moreover, as shown in Figure 3, the poorest rural households would like to increase their spending share on bananas, with their increased income, while they will significantly lower their sweet potato consumption in this case (Figure 3). Obviously, substitution exists between different staples with income growth, which indicates the different market opportunities for different staples in domestic markets, and must be taken into account in assessing growth and public investment options in the country. In the next chapter, we will further analyze such market opportunities based on the model simulations.

Figure 3: ABS and MBS for Rural Consumption of Banana and Sweet Potatoes



Source: Authors' calculation and estimation based on EICV2 (2005/06) data

39. We have to point out that declines in the marginal propensity to consume for some staple crops (such as sweet potatoes and cassava) may generate a misunderstanding of the size of the market for each individual product. For example, at the national level, the MBS for sorghum is 40 percent below the ABS (1.0 percent compared with 1.6 percent). One could assume that this implies an absolute decline in national sorghum consumption when per capita income rises. But determining this correctly depends on an analysis of the absolute consumption patterns by income groups, in addition to spending shares across commodities. According to the 2005–2006 EICV, Rwanda spent 14.2 billion Frw on sorghum consumption, including home consumption by farmers. Processed sorghum products, excluding beer made from sorghum, are also included. Surprisingly, the richest 20 percent of households consumed five times more sorghum in terms of value than the poorest of 20 percent of households, and in total, 36 percent of sorghum available in the country was consumed by the richest 20 percent of population. A similar situation exists for other staple and root crops, such as maize and cassava, for which the marginal propensity to consume falls with income growth, while the absolute amount of consumption will continue to rise.

40. The significant income, and hence expenditure, gap is the key reason for the difference in the absolute value of staple crop consumption between poor and nonpoor households. The total consumption expenditure of an average household among the poorest 20 percent of population is only one-seventh the level for an average household in the richest 20 percent in rural areas and one-thirteenth in the urban areas. Despite the often smaller ABS and MBS of food consumption reported for wealthy households, especially for certain staple foods, in absolute terms wealthy households spend 5.2 times as much as poor households on agricultural consumption in the rural areas and 9.6 times in the urban areas.

41. Both budget share and absolute spending analyses indicate that domestic demand for staples in Rwanda will need to increase rapidly to achieve pro-poor growth and redress the huge gap in the consumption of staple foods. If growth favors wealthy households, market opportunities for many staple foods will be limited. Wealthier consumers generally spend more on high-value and processed agricultural commodities and even more on nonagricultural commodities like industrial goods and services. This analysis helps to illustrate that market opportunities for agriculture, especially for staple foods and livestock sectors, critically depend on broad-based agricultural growth. This can directly increase the incomes of the majority of farmers and thus increase their consumption levels. When broad-

based agricultural growth is rooted in increased agriculture productivity, food prices can decrease without lowering farmers' incomes. Poor urban consumers also benefit from cheaper prices through increased consumption levels. In the following chapters, linkages between broad-based agricultural growth and poverty reduction are analyzed using the DCGE model developed for the study.

D. Patterns of Agricultural Production at the National and Subnational Levels

42. Rwanda has a diverse diet and hence a diverse agricultural production structure. The final row of Table 3 reports the share of each agricultural subsector in the total agricultural production revenue for the country as whole. While roots and tubers are the largest crop sector in the country, cereals, bananas, pulses and oilseeds are also important staples in both agricultural production and food consumption. Among root crops, potato and sweet potato are the two most important commodities, accounting for more than 27 percent of national agricultural production, followed by cassava, another 7 percent. As a single crop, banana is the most important staple crop, accounting for 17 percent of agricultural production. Among the cereal crops, Rwanda produces maize, rice, sorghum and wheat. While sorghum is the largest grain crop, followed by maize, share of rice in agricultural production (1.7 percent now) has been rising in the recent years, driven by increased demand and government supports. While coffee and tea are the most important export crops, excluding value addition from processing, their value in agricultural production is relatively low, accounting for 2.4 and 1.6 percent of national total agricultural production, respectively. Livestock is less important than crops in agricultural production, consistent with a traditional livestock system constrained by land availability.

43. The subnational level agricultural structure diverges significantly from the national average. The first part of Table 3 reports the regional distribution of agricultural production, taking subsector's national total as 100, while the second part of Table 3 reports the agricultural structure within each province, with the provincial total agricultural production being 100. In general, root crops are equally important for the four provinces except for Kigali. They are the most important staple products in the Northern province, accounting for 48 percent of its total agricultural production. In the Eastern province, bananas seem to be more important, representing 29 percent of province's agricultural production, and more than 50 percent of national banana production.. Share of cereal production, dominated by sorghum, is also high in the Eastern province, as more than 40 percent of the country's sorghum is produced from there, accounting for 6 percent of the province's total agricultural production.

Table 3: Agricultural Production Structure at the National and Provincial Levels

	Cereals	Roots & tubers	Banana	Pulses & oilseeds	Vegetable, fruits & o. cash	Coffee	Tea	Livestock
Share in subsector's national production								
Kigali	4.1	2.0	2.1	3.3	5.4	0.0	0.0	36.5
Southern	20.3	24.3	15.9	23.4	19.1	37.4	21.6	6.4
Western	21.7	27.2	18.6	22.5	20.2	41.2	49.3	8.7
Northern	18.2	26.1	12.2	19.6	16.1	21.3	29.1	21.1
Eastern	35.6	20.4	51.2	31.2	39.1	0.0	0.0	27.3
Share in each province's total agricultural production								
Kigali	8.3	16.7	8.5	10.3	17.8	0.0	0.0	38.4
Southern	8.5	43.1	13.1	15.0	12.9	4.3	1.6	1.4
Western	8.2	43.4	13.8	13.0	12.3	4.3	3.3	1.7
Northern	7.9	47.9	10.4	13.0	11.3	2.6	2.2	4.8
Eastern	10.2	24.9	28.9	13.7	18.2	0.0	0.0	4.1
National	8.8	37.4	17.4	13.5	14.3	2.4	1.6	4.6

Sources: Authors' calculation using Rwanda SAM

44. Export crops, on the other hand, are mainly produced in the Western province. Forty-one and 49 percent of coffee and tea, respectively, are produced in the Western province, while the rest is produced in the Southern and Northern provinces. There is no coffee and tea production in the Eastern province. While the share of vegetable and fruit production is the highest in this province, the current export opportunities are small for these crops.

45. As discussed in the previous chapter, the SAM and CGE model developed for this study disaggregate the agricultural sector to the district level, with 28 districts that report agricultural production included. Table 4 reports the most important producing districts for each individual crop included in the model. The importance is defined according to the national production share of a specific district. We also report which province each district belongs to in the same table. Sixteen districts appear in each column of the three ranks, totaling 38 district names (some districts appear more than once) in Table 4. If a district appears in the table more than once, it indicates that this district is an important producer for more than one type of crop. After dropping all double-counted districts, there are 18 districts that are the most important producers of the country for at least one crop. The last column of Table 4 also reports the production share of the top three districts in national total production for each crop. It shows that 38.4 – 100 percent of production of export crops such as tea, coffee and other cash crops, production is concentrated in the top three districts. Rice and wheat production is also relatively concentrated, as the three most important districts produce 48.4 and 58.7 percent of national rice and wheat, respectively. The next two most concentrated staples are maize (31.6 percent) and potatoes (33.3 percent). For the remaining crops, the top three producing districts account for less than one-third to one-fifth of national production. The fact that production of export and high value staple crops is concentrated in a few districts indicates that the gains from promoting growth in such crops are unlikely to be distributed evenly among districts and rural households. Whether such uneven distribution in high value production affects income distribution and poverty reduction is a policy relevant issue. The model simulations will try to provide an answer for this issue in the next chapter.

Table 4: Top Three Production Districts for Selected Crops

	Top 1		Top 2		Top 3		
	Region	District	Region	District	Region	District	Share of national production
Maize	West	Rusizi	North	Gakenke	West	Nyabihu	31.6
Rice	West	Rusizi	East	Nyagatare	West	Nyamasheke	48.4
Sorghum	East	Nyagatare	East	Bugesera	East	Gatsibo	26.8
Wheat	South	Nyaruguru	South	Nyamagabe	North	Rulindo	58.7
Potato	West	Ngororero	North	Gicumbi	North	Musanze	33.3
Sweet Potato	North	Gakenke	South	Muhanga	North	Rulindo	20.8
Cassava	South	Muhanga	South	Nyanza	East	Gatsibo	20.0
Other roots	West	Ngororero	South	Muhanga	North	Gakenke	28.9
Banana	East	Kirehe	East	Ngoma	East	Nyagatare	29.4
Pulses	North	Gakenke	East	Nyagatare	West	Karongi	20.7
Oil seeds	East	Bugesera	East	Gatsibo	East	Nyagatare	28.3
Vegetable	East	Nyagatare	East	Bugesera	East	Gatsibo	25.3
Fruits	East	Bugesera	North	Gakenke	East	Nyagatare	23.5
Coffee	North	Gakenke	West	Rusizi	West	Nyamasheke	38.4
Tea	North	Rulindo	West	Rusizi	North West	Gicumbi Karongi	56.8
O. cash crops	West	Karongi	North	Rulindo			100.0

4. MODEST POVERTY REDUCTION FROM A BUSINESS AS USUAL SCENARIO

46. After introducing the CGE model in Chapter Two and briefly discussing the key characteristics of Rwandan economy in Chapter Three, we are ready to apply the model to the Rwandan economy for growth and investment option analysis. To start this analysis, it is necessary to first apply this model for a scenario in which the economy will continue its current growth pattern. Thus, in this chapter, we first simulate a scenario of modest growth in both agricultural and nonagricultural sectors over next decade to 2015, based on historical data.

47. Due to huge production declines in 1994 in Rwanda, the year of the genocide, the post 1994 growth rate was comparatively high and has only recently slowed down. According to the World Development Indicator Dataset (World Bank 2008) in the entire post genocide period of 1995 to 2006, growth rates for GDP and agricultural GDP (AgGDP) were, respectively, 7.3 and 6.9 percent annually, while growth has slowed in both GDP and AgGDP in recent years. In the last four years of 2002 to 2006, the annual growth rate for GDP was 4.03 percent, AgGDP was0.53 percent. The poor growth performance in AgGDP in the recent period is the reflection of the severe drought in 2003 after the above normal harvest of 2002, followed by another bad year in 2004. Even considering a longer period (e.g., six years, between 2000 and 2006), the annual agricultural growth is still low, at 4.1 percent, in comparison with the total GDP growth, which is 5.4 percent in this period. The data from MINAGRI (2008) shows that total crop production grew at 4.7 percent annually between 2001 and 2007. During this period, 30 to 40 percent of crop production growth resulted from area expansion, while the remaining 60 to 70 percent was due to yield increases (and the majority of the increases represented recovery from the declines of 1994). Obviously, such growth is unsustainable, given the land constraint. Consequently, much more modest land-based expansion is assumed in the model, including the promotion of potential double and intercropping farming practices. Total crop area is assumed to increase by 0.5 percent per year, implying a cumulative increase of about 80,000 hectares of cultivated area from 1.69 million hectares in 2006 to less than 1.77 million hectares by 2015. The growth rate for individual crop yield is chosen to approximate their national average growth rate from 2001 to 2006, with certain adjustments for some crops with particularly high yields in this period (for example, rice grew at 8 percent and vegetables and fruits grew at more than 15 percent annually over this period).

48. 2006 was chosen as the base-year for the model, which means that the initial yield and area levels by crop used in the model are those reported by MINAGRI for 2006. Table 5a reports the national levels of cultivated area, yield and production for the base year (2006) by crop, while the base year's non-crop production in value terms, including livestock, other agriculture, industrial and service subsectors, is in Table 5b. The model results of base-run for the same variables are also included in the tables, together with their annual growth rates.

49. The DCGE model simulation results indicate that, with modest growth of 3.8 percent in agricultural production together with 5.1 and 5.7 percent annual growth in industry and services, national GDP grows at 4.8 percent annually and per capita GDP grows at about 2.9 percent. The model result for the growth rate of national GDP is higher than that in the period of 2002-2006 (4.0 percent annually) and slightly lower than in the period of 2001-2006 (5.1 percent annually). The model simulation results also show a modest reduction in national poverty and greater food insecurity with such growth. The poverty rate falls to 46.7 percent by 2015, compared with 60.3 percent in 2001 (EICV1, 1999–2001) and 57.0 percent in 2006 (EICV2, 2005-06) although the rate was higher in rural areas (63.4 percent) than in urban areas (28.8 percent). With such a reduction in the poverty rate, together with population growth, the poverty population would only decline by 220,000 from the current level of 5.45 million to 5.23 million by 2015. The poverty reduction in the model as a result of GDP growth is slightly more optimistic than what happened in the six years (1999 – 2005) between the two runs of household surveys (EICV1 and

EICV2). During this period, per capita GDP grew at 2.3 percent annually while the national poverty rate fell from 60 percent to 57 percent, which indicates that for each 1 percent annual growth in per capita GDP, the national poverty rate fell by 0.42 percent (not percentage point). In the base-run of the model, 1 percent of per capita GDP growth results in a 0.71 percent decline in the national poverty rate. The model results also show that the apparent gap between supply and demand in the food sector would continue to increase. Imports of maize will double, and rice imports will rise by 70 percent by 2015 from their current levels, making Rwanda more dependent on imports or food aid to meet its basic needs for many staple foods.

Table 5a: Crop Area, Yield & Production, Current & Model Results of Baseline (National Level)

	Area			Yield			Output		
	2006 (000 ha)	2015 (000 ha)	Annual growth (%)	2006 (mt/ha)	2015 (mt/ha)	Annual growth (%)	2006 (1000 mt)	2015 (1000 mt)	Annual growth (%)
Wheat	23	25	1.1	0.9	1.2	3.8	20	30	5.0
Maize	115	126	1.0	0.8	1.0	2.8	92	129	3.9
Rice	14	18	3.0	4.5	4.9	0.9	63	89	4.0
Sorghum	170	162	-0.6	1.1	1.5	3.7	187	246	3.1
Potatoes	140	149	0.7	9.2	11.9	2.9	1,286	1,769	3.6
Sweet potatoes	139	136	-0.2	5.6	6.9	2.4	777	940	2.1
Cassava	119	123	0.4	6.3	8.0	2.8	743	988	3.2
Other roots	25	29	1.7	5.0	6.0	2.2	125	177	3.9
Pulses	388	410	0.6	0.8	1.0	2.7	298	402	3.4
Vegetables	51	51	0.1	5.4	7.3	3.5	271	374	3.6
Bananas	366	393	0.8	7.2	10.0	3.6	2,652	3,927	4.5
Fruits	34	32	-0.6	9.9	14.3	4.1	339	463	3.5
Oil crops	59	61	0.4	0.6	0.8	3.2	36	50	3.6
Coffee	29	34	2.0	0.7	1.1	4.1	21	36	6.2
Tea	13	16	2.0	1.2	1.7	4.1	16	27	6.2
Other exports	8	9	1.2	19.9	26.5	3.2	162	240	4.5
	1,692	1,775	0.5						

Source: 2006 is calculated by the authors from MINAGRI (2007) and 2015 is the CGE model results.

Table 5b: Non-Crop Production, Current and Model Results of Baseline

	Output		
	2006 (Millions Frw)	2015 (Millions Frw)	Annual growth (%)
Bovine cattle	13	19	4.2
Sheep and goats	2	3	4.5
Swine	1	2	3.8
Poultry	1	2	4.6
Raw milk	8	15	7.3
Eggs	1	3	7.5
Other livestock	1	3	7.0
Forestry	39	54	3.8
Fishing	6	9	4.8
Mining	11	16	3.7
Meat, fish and dairy products	5	8	5.6
Processed cereals	5	9	6.7
Processed coffee	8	17	8.3
Processed tea	9	16	6.7
Bakery, processed sugar	1	2	3.9
Traditional beverages	17	25	4.6
Modern beverages	9	15	5.7
Tobacco	3	5	3.9
Textile and clothing	5	11	10.3
Wood, paper and printing	4	5	4.1
Chemicals	7	11	5.5
Non-metal minerals	9	13	3.8
Other manufacturing products	12	16	3.7
Electricity, gas and water	9	14	4.5
Construction	97	147	4.8
Wholesale and retail trade	135	199	4.4
Hotels and restaurants	12	19	5.3
Transports	52	95	7.0
Communication	33	66	8.0
Finance and insurance	74	135	6.9
Real estate	90	166	7.1
Business services	26	49	7.2
Repair	10	18	7.4
Public administration	93	133	4.0
Education	62	91	4.3
Health	20	30	4.4
Other personal services	14	21	4.4

Source: 2006 is drawn from Sam and 2015 is for the CGE model results.

5. WHICH SECTORS CONTRIBUTE THE MOST TO GROWTH AND POVERTY REDUCTION?

50. Quantitative assessment of how the growth of each agricultural subsector will contribute to the overall economic growth and poverty reduction is necessary for understanding the role of agriculture in development. Recent policy debates on agricultural development in Africa have been around issues such as the role of smallholders and the role of food staples versus export crops. Despite numerous Asian case studies that have proved the important role of agriculture in development, there is doubt about whether agriculture can successfully generate enough growth in Africa today (see, for example, Collier 2002; Maxwell and Slater 2003; Ellis 2005). With rapid expansion in international agricultural trade, many see high-value commodities such as fruits, flowers and vegetables as the best opportunities for African farmers. Many African countries are being encouraged to expand into high-value, nontraditional exports, and to improve the quality of their traditional tree crop exports. In Rwanda, these sectors, such as coffee and tea, have also attracted more attention and support from the government. In this chapter we design a series of subsector agricultural growth scenarios to specifically address these issues. Based on the actual growth targets at the agricultural subsector level developed by the government of Rwanda, we will quantitatively assess the following important policy issues: (a) What is the contribution of each agricultural subsector to broad growth and poverty reduction goals? (b) Why is staple growth is so important for overall economic growth and poverty reduction? (c) How can staples-led growth help the country to meet the CAADP six percent growth goal and achieve the first MDG to halve poverty? (d) What is the role of the export agricultural sector, and (e) What is the role of nonagricultural growth in this development process?

A. DESIGNS OF GROWTH SCENARIOS TO ASSESS SUBSECTORS' CONTRIBUTIONS TO ECONOMYWIDE GROWTH AND POVERTY REDUCTION

51. To prepare for the country's growth and poverty reduction strategies, a series of targets were set for many agricultural subsectors or specific crops and products. These targets are the result of broad consultation within the country, stock taking of yield and productivity potential, and comparison with similar neighboring countries in Sub-Saharan Africa. Based on these actual growth targets, we have designed 21 scenarios to assess each major agricultural subsector's contribution to overall growth and poverty reduction. The detailed relationship between the targeted subsectors and model scenarios are presented in Table 6. Under each scenario, additional growth is assumed for a specific agricultural subsector between 2006 and 2015, while productivity growth in the other subsectors is maintained at baseline levels.

Table 6: Model Scenarios

	Grains				Root crops				
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 19
Maize	X			X					X
Rice		X		X					X
Wheat			X	X					X
Sorghum				X					X
Cassava					X			X	X
Potatoes						X		X	X
Sweet potatoes							X	X	X

	Banana		Pulses/oilseed				
	Scenario 9	Scenario 10	Scenario 11	Scenario 12			Scenario 19
Bananas	X						X
Pulses		X		X			X
Oilseeds			X	X			X
		Export crops			Livestock		
	Scenario 13	Scenario 14	Scenario 15	Scenario 16	Scenario 17	Scenario 18	Scenario 19
Coffee	X		X				
Tea		X	X				
O. export crop			X				
Poultry				X		X	X
Egg				X		X	X
Beef					X	X	X
Mutton					X	X	X
Other meat					X	X	X
Milk					X	X	X
fish						X	X

Scenario 20 is for all agriculture and Scenario 21 is for all agricultural and nonagricutlural sectors

52. The government of Rwanda has placed a special focus on the promotion of cereal growth, and hence, the first four scenarios, Scenarios 1 - 4, focus on the growth in this subsector with national targets for maize, rice, and wheat individually in Scenarios 1–3. Within cereal production, rice has attracted more attention in public investment. Increased public investment in marshland development and the introduction of high-yield varieties have significantly increased the rice production area and output in recent years. This strategy is expected to continue in the next 10 years under the national rice development program (Fowler et al. 2007), and hence, as shown in Table 7, the targeted annual growth in rice output is about 10 percent in the model scenarios.

53. The production of maize in Rwanda is low compared with the national demand. The existing industrial processing capacity of maize is always above the domestic supply (Fowler et al. 2007) and imports of maize account for more than a quarter of domestic demand (Table A1(a) in Appendix I). Development of maize production is constrained by its extremely low level of yield. The national level of maize yield is only 0.8 metric ton per hectare (mt/ha), a level lower than most neighboring African countries in the region (World Bank 2007). While the targeted yield of 1.4 mt/ha for maize yield is very modest, it still requires an annual growth rate of six percent in the next 10 years (Table 7).

54. Besides evaluating the growth and poverty reduction effect of each individual grain crop in Scenarios 1 – 3 when the targeted growth can be met individually in the next 10 years, Scenario 4 is designed to combine the first three scenarios, together with modest growth in sorghum, to simulate joint growth in grain production. As in the case of the cereal scenarios, Scenarios 5 – 8 are designed to focus on growth in root crops, the subsector that contributes the most to the daily diet of the majority of rural and urban households. In recent years, the government has launched a national program to promote special cassava seed multiplication in order to tackle the mosaic virus problem that had badly affected cassava production in the country (Fowler et al. 2007). With the continuation of this program, together with a new project to promote the low-cost multiplication of tubers and fruit species, root crops are

targeted to grow at 5 percent annually in the next 10 years (Table 7). A similar national program has also been launched for bananas, the most important single food security crop in the country. Scenario 9, hence, is designed to focus on banana growth and is used to evaluate its potential contribution to both growth and poverty reduction. Additional scenarios, Scenarios 10–12, are designed for the remaining staple crops, i.e. pulses and oilseed crops.

55. As we discussed in Chapter Three, agriculture-based products account for 70 to 80 percent of the country's total export revenues. Thus, the two most important export crops, coffee and tea, are always at the top of the government's agenda for investment in agriculture. The national export promotion strategy currently focuses on improving coffee and tea's competitiveness by increasing the quality of the production and diversification. Through capacity building of farmers' organizations and new technology promotion, it expects improved quality of coffee and tea products throughout the entire production cycle, which will create more export opportunities for these two products. Thus, Scenarios 13–14 are designed for these two export crops—coffee and tea—and Scenario 15 combines the two traditional export crops with the other nontraditional export crops (such as vegetables and fruits) to capture potential growth in both traditional and nontraditional export commodities.

56. Compared with crop production, the livestock subsector is relatively small in the Rwandan agricultural economy. The small size of this sector in the economy is mainly due to the high proportion of local species that have low productivity level, and the generally poor standards of animal husbandry (Fowler et al. 2007). On the other hand, demand for livestock products is expected to grow faster than for many other staple food crops, due to the high income elasticities for them. Many different government projects, together with some NGO projects have been launched recently to promote livestock production, and most are expected to continue in the next 10 years. Thus, Scenarios 16–18 are designed for evaluating the growth and poverty effect of livestock growth. Specifically, Scenario 16 focuses on poultry, Scenario 17 focuses on cow, goat and sheep and milk production, while Scenario 18 focuses on the total livestock growth, together with the growth in fish.

57. After evaluating individual agricultural subsectors' potential contribution to the overall economic growth and poverty reduction in Scenarios 1 – 18, Scenario 19 is designed to simulate the joint effect of growth in all agricultural staples (both crops and livestock). In other words, this scenario will be the combination of Scenarios 1–3, 5–7, 9–11, and 16–17. The purpose of this scenario is to quantitatively assess the importance of staple-led growth in improving the country's food security, overall economic growth, and poverty reduction. Scenario 20 combines growth in staple crops and livestock with growth in export crops. Using this scenario, we can assess whether the CAAD six percent growth target for the agricultural sector can be supported by the growth targets set for individual agricultural products and developed by the government, and the implication of six percent agricultural growth for MDG1, i.e., with six percent of agricultural growth in the next 10 years whether the country will meet the MDG1 by the end of the 10 years. Finally, Scenario 21 considers comparable growth in nonagricultural sectors, in addition to growth in the agricultural sector, which will be used to evaluate the linkage and synergy effects of such growth and how it will help the country achieve its broad development goals and MDG1.

58. We must point out that national growth projections for agricultural products often take the form of targeted production output and area expansion. To be able to simulate such growth in the model, most production and area targets were converted into average annual growth rates in productivity for 2007–15, based on the level for 2006, while for rice, coffee, tea and nontraditional export crops, additional growth is also due to land expansion, as new land is expected to be developed and brought into production under these respective scenarios. The resulted yields by 2015 and growth rate for crop production under Scenario 20, i.e., growth in all agricultural sectors, are reported in Table 7a, and growth rate for non-crop production is in Table 7b.

Table 7a: Growth in Yield and Crop Production under Agricultural Growth Scenario (Scenario 20)

	Yield			Output		
	2006 (mt/ha)	2015 (mt/ha)	Annual growth (%)	2006 (1000 mt)	2015 (1000 mt)	Annual growth (%)
Wheat	0.9	1.4	6.0	20	37	7.2
Maize	0.8	1.4	6.0	92	170	7.0
Rice	4.5	4.7	0.5	63	143	9.6
Sorghum	1.1	1.6	4.4	187	264	3.9
Potatoes	9.2	14.7	5.3	1,286	2,211	6.2
Sweet potatoes	5.6	9.0	5.3	777	966	2.5
Cassava	6.3	10.3	5.7	743	1,151	5.0
Other roots	5.0	13.3	11.6	125	298	10.1
Pulses	0.8	1.1	3.8	298	451	4.7
Vegetables	5.4	7.8	4.2	271	403	4.5
Bananas	7.2	11.0	4.8	2,652	4,642	6.4
Fruits	9.9	14.5	4.3	339	515	4.7
Oil crops	0.6	1.0	5.1	36	62	6.2
Coffee	0.7	1.2	5.9	21	55	11.3
Tea	1.2	1.7	4.2	16	41	11.1
Other exports	19.9	29.9	4.7	162	354	9.1

Source: CGE model simulation results

Table 7b: Growth in Non-Crop Production under Agricultural Growth Scenario (Scenario 20)

	Output		
	2006 (Millions Rwf)	2015 (Millions Rwf)	Annual growth (%)
Bovine cattle	13.4	24.9	7.2
Sheep and goats	1.8	3.7	8.1
Swine	1.2	2.3	7.4
Poultry	1.4	3.2	9.3
Raw milk	7.8	27.5	15.0
Eggs	1.3	4.6	14.9
Other livestock	1.5	7.5	19.6
Forestry	38.9	79.2	8.2
Fishing	6.0	11.3	7.3

Source: CGE model simulation results

B. The Six Percent CAADP Growth Target is Reachable

59. With detailed production targets at the agricultural subsector level developed by the government of Rwanda, questions such as whether such growth targets can support the broad goal of six percent of total agricultural growth, and how such growth contributes to the realization of MDG1 remain to be answered. Scenario 20 is designed to model the joint effects of growth across agricultural subsectors. The

simulation of the model shows that to reach the desired targets at the agricultural subsectoral level by 2015, agricultural GDP would need to grow at 6.3 percent from 2007 to 2015—almost doubling baseline growth. This represents a total GDP growth of 6 percent, compared with the 4.8 percent baseline level. If additional yearly growth of 2.8 and 2.4 percent is assumed to occur in the industrial and service sectors -- comparable with targets of the government (Scenario 21) -- interlinkages between nonagriculture and agriculture fuel agricultural growth to 6.5 percent per year, while total GDP growth rises to 7.4 percent per year. At this rate, per capita GDP grows at 5.5 percent annually, doubling the baseline level. With such high growth rates, national poverty by 2015 falls to 35.5 percent—24.5 percentage points lower than the rate in 1999 and 11.2 percentage points lower than the 2015 baseline. If such growth trends continue until 2020, it would allow the country to achieve MDG1, halving the 1999-2001poverty rate of 60 percent, by 2020.

C. DIFFERENTIAL INCOME AND POVERTY REDUCTION EFFECTS

60. Growth may not benefit rural households equally. Empirical studies in other countries often show that rapid economic growth does not always result in shared growth (Akita and Kawamura 2002; Zhang and Kanbur 2004). Differences in poverty reduction and income growth across regions have also been observed in China (Chen and Ravallion 2000). Thus, it is essential to further assess the income and poverty effects of agricultural growth at the household level.

61. In the case of Rwanda, the simulation results indicate that rapid agricultural growth benefits the majority of rural households, and that the distribution of benefits is relatively equal. Nevertheless, the household group with the smallest landholding appears to benefit less than the household group with medium and large landholdings. Under Scenario 21, the scenario in which both agriculture and nonagriuclture grow following the targets, annual income growth for the small farm group at the national level is 8.5 percent, while it is 9.0 percent for the household group with greater land holdings, 0.5 percentage points higher (Table 8, second column). While rural poverty falls across provinces and household groups, at the national level, poverty falls more among greater landholding groups than among the small farm group (Table 8, last column). As the initial poverty rate is already higher among small farmers, the difference in the poverty rate between these two types of rural households is further widened by 2015. At the provincial level, the poverty rate is highest in the Southern province for both household groups. While the initial poverty rate of the Southern small farm group is 2.5 percentage points higher than the Southern other farm group, the poverty gap between these two groups increases to 4.9 percentage points by 2015, although poverty rate falls in the two groups.

Table 8: Rural Income Growth and Poverty Reduction by the Two Farm Household Groups under Agricultural and Nonagricultural Growth Scenario (Scenario 21)

	Income growth			Poverty rate		
	Baseline growth rate	Growth rate under Scenario 21	Additional growth fr baseline	2006	By 2015 in Scenario 21	Poverty reduction
Rural small farm households						
Kigali	5.27	7.86	2.59	50.4	30.8	-19.6
Southern	5.91	8.44	2.53	72.7	47.4	-25.3
Western	6.09	8.82	2.73	65.6	40.2	-25.4
Northern	5.78	8.37	2.58	66.8	39.6	-27.2
Eastern	5.43	8.09	2.65	54.0	31.0	-23.0
National	5.83	8.47	2.63	64.9	39.9	-25.0
Rural medium and large farm households						

Kigali	5.05	7.60	2.56	50.4	32.9	-17.5
Southern	6.98	8.97	1.99	70.2	42.5	-27.7
Western	7.47	9.77	2.31	63.2	39.9	-23.3
Northern	7.06	9.35	2.29	58.8	33.5	-25.3
Eastern	5.77	8.43	2.66	48.7	24.1	-24.6
National	6.65	9.03	2.38	58.4	33.1	-25.2

Source: CGE model results

D. STAPLE CROP GROWTH IS MORE PRO-POOR

62. The different poverty reduction effects of growth at the provincial level and among different types of farm households relate to the different income sources of farmers, and the local agricultural structure they face. Thus, as differing growth–poverty linkages could occur in the agricultural subsector, it is important to understand such linkages in order to provide insightful information for designing a pro-poor growth strategy. For this purpose, the poverty–growth elasticity was calculated to enable direct comparison of the various poverty-reduction outcomes.[5] This elasticity was calculated for the two broad agricultural products—staple food and export crops—as well as for each individual crop or livestock product for which targeted growth was individually simulated in Scenarios 1 – 17. The poverty–growth elasticities are endogenous outcomes from the model results. Growth affects individual households differently due to heterogeneity across household groups. As shown in the above analysis, with different income sources and land size, growth in income and reduction in poverty across household groups differ considerably from average changes at the national level. To capture growth–poverty linkages, changes in the distribution of incomes, which are primarily determined by a country's initial conditions, need to be understood. For example, households with greater opportunities to produce higher value export agricultural products may be better positioned to benefit from export agriculture, but since households involved in export crops are usually less remote and less poor, economic growth driven by agricultural exports may in fact have less of an impact on poverty. In contrast, staple crops are a more important source of agricultural incomes in the poorer (and more remote) regions of the country. Hence, because staples have a greater impact as an income source for the poor, growth in the production of staple crops is expected to be more pro-poor than growth in the production of agricultural exports.

63. While agricultural growth is generally pro-poor, a gap in the poverty–growth elasticities between staple crops, such as grains and roots, and agricultural exports indicates the importance of staples for poorer rural households (Table 9). If economywide growth is led by growth in grain crops (Scenario 4), a 1 percent additional growth in per capita GDP leads to an additional 1.74 percent decline in the national poverty rate. The growth to poverty reduction effect is particularly large in the case of maize with an elasticity of 2.39. On the other hand, if economywide growth is led by growth in export crops, including both traditional export crops such as coffee and tea and nontraditional ones such as vegetables and fruits

[5] 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:

$$\frac{\Delta P_0 / P_0}{\Delta GDP_{pc} / GDP_{pc}} = \frac{\Delta P_0}{\Delta GDP_{pc}} \cdot \frac{GDP_{pc}}{P_0},$$

where ΔP_0 and ΔGDP_{pc} are average annual changes (from the base-year) in the poverty headcount rate and level of per capita GDP; and P_0 and GDP_{pc} are the base-year poverty headcount rate and per capita GDP. The poverty–growth elasticity measures the percentage change in the poverty headcount rate caused by a 1 percent increase in per capita GDP. This is *not* equivalent to a percentage point change in the poverty headcount rate.

(Scenario 15), a 1 percent additional growth in per capita GDP reduces the national poverty rate by 1.68 (Table 9).

64. The model results indicate that putting staples at the top of the agenda can promote broader economic progress and poverty reduction in Rwanda. This is true in general in many African countries, as smallholders comprise more than 70 percent of the continents farmers (Johnson et al, 2003). A wide range of research has also demonstrated the importance of food staples in driving growth and contributing to a dynamic structural transformation of rural economies (Byerlee et al, 2005; Bezemer and Headey, 2008; Hazell and Diao, 2005; World Bank, 2008). Acceleration in staples production has also been found to produce second and third round effects on the broader economy by reducing food prices for urban consumers, curbing overall inflation, and releasing scarce foreign exchange for the importation of goods that are typically unsuited to production within Africa (Diao et al. 2007). And in the longer run the productivity growth in staples agriculture will facilitate a more fundamental transformation in the broader economy through new opportunities for industry (e.g. agro-processing), growth opportunities for rural nonfarm activities (Haggbalde et al, 2007), increased regional and international trade, and new employment options through expanded migration.

Table 9: Poverty Reduction–Growth Elasticity

Additional percent reduction in national poverty rate with one percent of additional per capita GDP growth	
Additional GDP growth led by	
Maize growth	-2.39
Rice growth	-1.86
Wheat growth	-1.60
Cassava growth	-1.60
Potato growth	-1.40
Sweet potato growth	-1.65
Pulses growth	-2.59
Banana growth	-2.05
Oil crop growth	-2.17
Coffee growth	-1.81
Tea growth	-1.63
Other export crop growth	-2.27
Poultry growth	-0.45
Other livestock growth	-1.38
Fish growth	-2.11
Grain growth	-1.74
Root crop growth	-1.54
Livestock growth	-1.35
Export crop	-1.68

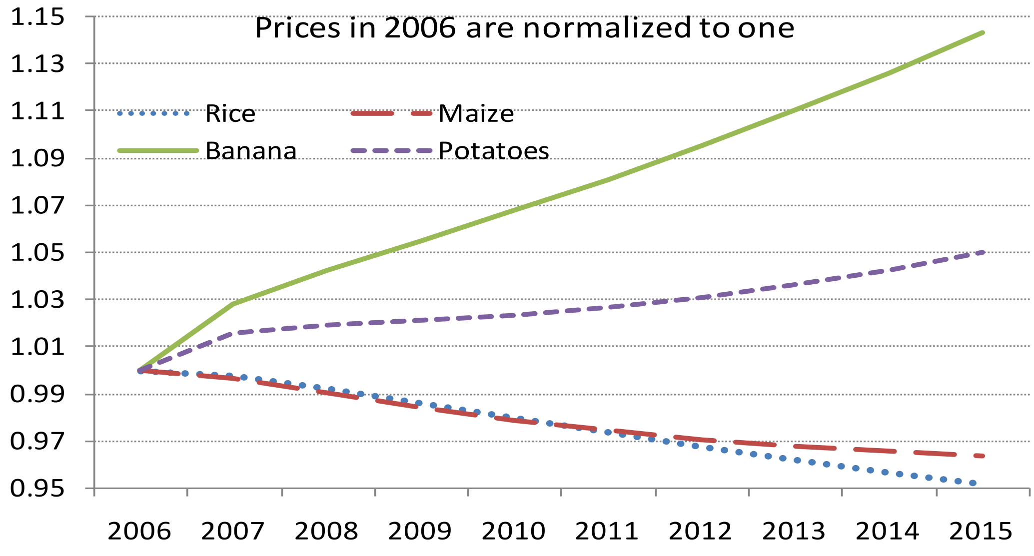
growth	
Agricultural growth	-1.53
Agriculture with transport	-1.37
Nonagricultural growth	-0.49
All sectors' growth	-0.97

Source: CGE model results

E. Growth Effects on Agricultural Prices and Trade

65. Growth may not always benefit producers, especially when it is unbalanced and only occurs in a few agricultural subsectors. When growth targets are set too high for some agricultural production, when there is not enough demand from domestic markets, and when it is difficult to export in order to meet with increased supply, prices can fall significantly. This may hurt some farmers if they cannot adopt more productive technology in their production process. For this reason, it is necessary to look at the price effect of growth, particularly prices for the agricultural products broadly grown by small farmers. We focus on Scenario 21, in which both agricultural and nonagricultural growth is accelerated and have selected seven crop and livestock commodities to discuss the price effects.

Figure 4: Change in Prices for Selected Four Staple Commodities with Agricultural and Nonagricultural Growth (Scenario 21)

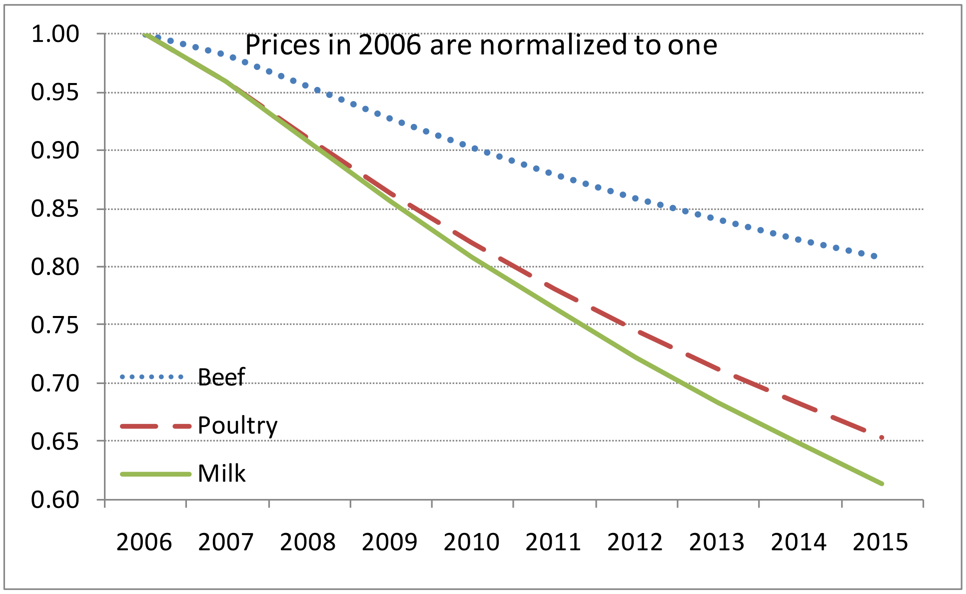


Source: CGE model results

66. As shown in Figure 4, prices for most staple crops will either not decline or decline modestly if agricultural and nonagricultural sectors grow side by side. This result is consistent with the information drawn from the two runs of household living conditions surveys that have been discussed in Chapter Three. Given the current extremely low level of income (and hence consumption) in Rwanda, the demand for staple crops increases with income growth if broad growth can bring more income to the majority of rural and urban households, particular poor households. Because of this, the domestic market will become

the dominant destination to absorb the increased supply for most staple crops. In fact, imports of maize actually grow quite rapidly, driven by increased food and feed demand, indicating additional room for further growth in maize production. Similarly, the domestic price for rice is expected to fall modestly, causing import substitution. While domestic demand for rice doubles in the next 9 year, ratio of imports to the domestic consumption falls from current 40 percent to below 30 percent by 2015. This is also important for the country to reduce import dependence on staple food, and hence, improve the food security situation at the national level.

Figure 5: Change in Prices for Selected Livestock Products and Vegetables with Agricultural and Nonagricultural Growth (Scenario 21)



Source: CGE model results

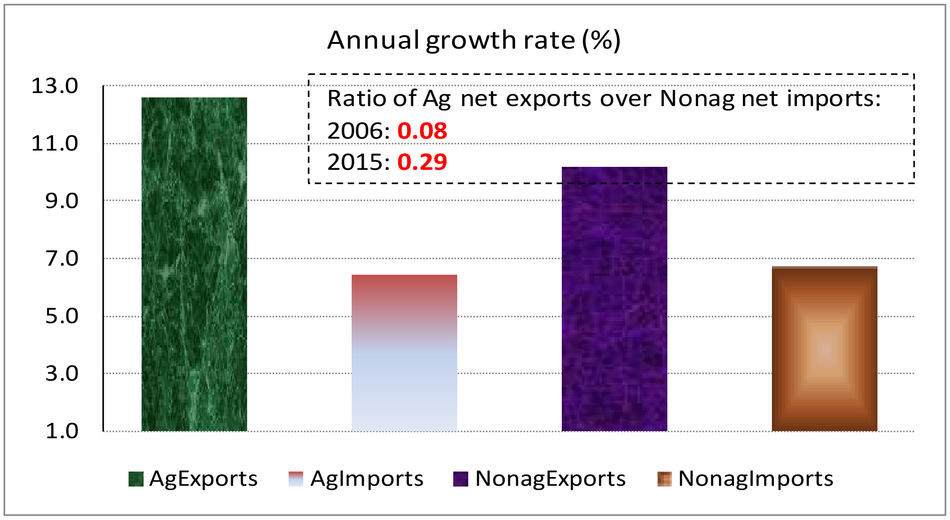
67. We display the changes in prices for selected livestock products in Figure 5. As the growth targets are very high for these commodities, it is not surprising to see that, although the income elasticity is high for these commodities, prices for these commodities fall dramatically and poultry and milk prices fall by 35 – 40 percent in the nine years. Starting from a very small base, poultry and milk production and consumption will have double digit growth rate in this period. While declined poultry and milk prices benefit consumers, the low prices may push small farmers out of production, unless they significantly improve their productivity.

68. As we have discussed in Chapter Three, Rwanda depends heavily on agriculture for export revenues. Agricultural exports account for 90 percent of total exports. This situation will be further enhanced with rapid growth in export sectors. Under Scenario 21, growth in coffee and tea reaches 16 and 14 percent annually and exports of nontraditional agricultural products grow at 28 percent annually. These result in the growth of total agricultural exports by 13 percent each year (Figure 6). On the other hand, agricultural imports grow much more slowly, at less than 7 percent, due to import substitution in many agricultural food commodities.

69. While nonagricultural exports grow more rapidly than the nonagricultural imports, the amount of nonagricultural exports is much smaller than the imports. This results in an increased deficit of nonagricultural trade. Thus, the agricultural trade surplus becomes increasingly important to finance nonagricultural imports. We calculate a ratio of agricultural trade surplus over nonagricultural trade

deficit, and, as shown in the box of Figure 6, this ratio rises from current about 0.08 to 0.29 by 2015, when both agricultural and nonagricultural sectors grow side by side under Scenario 21.

Figure 6: Growth in Agricultural and Nonagricultural Trade under Scenario 21



Source: CGE model results

6. AGRICULTURAL SPENDING REQUIRED TO ACHIEVE CAADP AND POVERTY REDUCTION GOALS

70. Achieving the growth required in the Rwanda's agricultural sector for meeting both CAADP and poverty reduction goals is a challenging task. In addition to an improved policy environment, public investment is instrumental not only in improving public services and provision, such as research and extension, rural infrastructure, and education, but also in attracting private investment and inputs. The following discussion focuses on public sector spending on agriculture required to achieve these goals, and the potential returns to investments into different subsectors of agriculture.

71. The previous analysis indicates that agricultural GDP could grow at more than 6 percent annually in the next nine years if agricultural commodity or subsector growth can be achieved to reach national targets set up by the government. These growth targets are consistent with CAADP goals and will significantly reduce poverty. The model results show that with more than six percent agricultural growth together with rapid growth in the nonagricultural sector, Rwanda will be able to achieve the MDG1 of halving poverty by 2020.

72. To promote rapid agricultural growth and greater poverty reduction, the Government of Rwanda has already committed to increasing its investment in agriculture, and many agricultural development programs are being implemented. For example, three types of investment programs are currently being implemented for marshland development, among which the national rice development program is estimated to be valued at about 330 million RWF. Many development strategies targeting sectoral productivity, production capacity, commodity quality, and competitiveness are also underway. Moreover, the government has also increased investment in rural infrastructure, markets, and supply chains to improve the external environment for agricultural growth and rural development.

73. While all these interventions and investments will build a solid foundation for higher agricultural growth in the future, the short implementation period makes the ex post assessment of the impacts of these endeavors on future growth difficult. For this reason, an ex ante approach is developed for this report. In the first two sections of this chapter, we focus on the amount of public investment in agriculture required for achieving the growth targets discussed in the previous sections. In the rest of this chapter, we introduce the newly developed ex ante approach and apply this approach to assess the potential returns of agricultural investment, and the relationship between targeted growth and increased agricultural investment at the subsector level.

A. CURRENT AGRICULTURAL SPENDING TRENDS

74. Published data in the Annual Finance Laws, 1999–2006 (MINECOFIN 2006) shows that the share of public resources allocated to the agricultural sector has declined in Rwanda, even though the absolute value in current terms has increased modestly. The share of government spending allocated to agriculture fell to less than 4 percent in recent years, compared with levels as high as 8.6 percent in 2002 (Table 10). While the government's total spending grew more than 10 percent from 2001 to 2006, the growth rate of agricultural spending (in real terms) is negative for this period. The share of agricultural funding allocated to development is relatively high, averaging more than 12.3 percent per year during 2000–06, vs. 5.2 percent of agricultural spending on average in the total national budget during this period. Nevertheless, even in this case, the share of resources allocated to agriculture has declined, from an average of 16 percent in the early 2000s to less than 10 percent in recent years.

B. ESTIMATED TOTAL SPENDING REQUIRED FOR AGRICULTURAL GROWTH

75. How much agricultural spending is really required to achieve CAADP and poverty reduction goals? We utilize a two-step approach to assess this question. The first step is to estimate the agricultural growth required to achieve development objectives using the so-called "poverty reduction elasticity." For example, to achieve the MDG1, it would require an annual growth rate more than 6.5 percent in the agricultural sector between 2007 and 2020. The second step involves estimating the required agricultural spending to achieve the required agricultural growth targets. This relationship is termed "agricultural growth elasticity," and it can be estimated econometrically using historical data. Needless to say, the impact of many investments on growth cannot be realized immediately; hence, a comparatively longer time series is needed to achieve a robust estimation. However, official national agricultural spending data are only available for 2001–06, so additional data (1995–2000) were drawn from the International Monetary Fund (IMF 2004).

Table 10: Economic Growth and Government Budget Allocation

Indicator	1999	2000	2001	2002	2003	2004[a]	2005[a]	2006	Growth rate (percent)
1999 constant RWF (billions)									
AgGDP	270	283	295	330	333	339	359		4.2
Non-AgGDP	375	400	434	468	473	499	532		4.8
GDP	645	684	730	798	805	838	890		4.6
Agricultural spending			11.1	12.6	8.7	10.5	8.9	8.3	–6.5
Agricultural development spending	14.6	6.5	10.4	6.7	6.6	7.8	5.6	5.4	–5.8
Nonagricultural spending			168	134	215	249	250	244	11.8
Total spending	174	124	179	146	224	260	258	252	10.8
Total development spending	77	64	55	55	58	69	77	69	4.2
Ratio to GDP or total spending (%)									
Agricultural spending/total spending			6.2	8.6	3.9	4.0	3.4	3.3	
Agricultural spending/AgGDP			3.8	3.8	2.6	3.1	2.5		
Agricultural development spending/total development spending	19.0	10.2	18.9	12.3	11.4	11.4	7.2	7.8	
Nonagricultural spending/non-AgGDP			23.0	16.8	26.8	29.8	28.0		
Total spending/GDP	27.0	18.1	24.5	18.3	27.8	31.0	29.0		

Source: Annual Finance Laws 1999–2006 Government of Rwanda.

[a.] *Values are author estimates.*

76. The estimated elasticity of agricultural growth with respect to agricultural spending during 1995–2005 was 0.17—that is, for every 1 percent growth in agricultural spending, 0.17 percent AgGDP growth results. This elasticity is much lower than the African average of 0.366, based on a cross-country estimation using a much longer data time series. Due to Rwanda's recent history before 1995, the estimated coefficient between agricultural spending and agricultural growth may not represent the true relationship in the future. Moreover, many investment projects were initiated only recently and their potential effects of agricultural growth cannot be captured in econometric analysis. For these two reasons, the elasticity based on the cross-country study is also used in calculating the required levels of public spending (Table 11). Two sets of values are reported, corresponding to the two different agricultural growth scenarios (Scenario 20 corresponding to CAADP scenario and Scenario 21 corresponding to MDG scenario in the table). As discussed above, with 6.5 percent of annual growth in AgGDP, together with a similar growth rate in the nonagricultural sector, total GDP will grow at 7.4 percent annually in the next nine years in Scenario 21. Required agricultural spending under this scenario is reported under "MDG target" (Table 11, columns 4 and 5), while required spending corresponding to Scenario 20 is reported in Table 11, columns 2 and 3 in which agricultural growth is 6.3 percent. A 6.3 percent increase in AgGDP per year from 2007 to 2015 requires associated growth in agricultural investment (represented by the agricultural development funds) at 35.9 percent annually with the low elasticity and 18.4 percent with the high elasticity. Assuming that the government's allocation to nonagricultural sectors is proportional to nonagricultural GDP, and agricultural nondevelopment spending is proportional to AgGDP, the total government budget is estimated to grow at 6.7 percent with high elasticity and at 8.2 percent with low elasticity. As agricultural spending grows much more rapidly than the total spending, the agricultural spending share will rise to 4.4 or 6.6 percent in 2010 and 9.5 or 17.6 percent in 2015. The lower number corresponds to high elasticity, while the higher number corresponds to low elasticity (Table 11, columns 2 and 3). Obviously, whether the government will meet requirements of the Maputo declaration of allocating at least 10 percent of its total budget to agriculture depends on whether agricultural spending can stimulate agricultural growth efficiently. With (less efficient) low elasticity, the government needs to allocate 18 percent of its total budget to agriculture by 2015, while if spending has (more efficient) high elasticity, about 10 percent of the total government budget would be needed to support 6 percent annual agricultural growth.

77. As previously identified, 6 percent annual agricultural growth for 9 years is insufficient for the country to meet the goal of halving national poverty by 2020; instead, a growth rate higher than 6.5 percent per year during 2007–20 is needed (the MDG scenario has a similar growth rate as that under Scenario 21 but with a longer time period between 2007 and 2020, instead of 2007 – 2015). Estimates of the required spending to achieve this level of growth are provided in Table 11 (columns 4 and 5), indicating that agricultural spending needs to grow at the extremely high rate of 45.6 percent annually (between 2007 and 2015) if the investment has a low growth elasticity, or 22.6 percent if the investment can be more efficient (that is, with a high elasticity). Assuming the growth in nonagricultural spending is proportional to nonagricultural GDP and agricultural nondevelopment spending is proportional to AgGDP, the total government budget would grow at 8.3 or 12.2 percent annually, depending on whether the elasticity was high or low. The share of agricultural spending would rise to 5.2–9.2 percent in 2010 and 12.0–34.5 percent in 2015, again based on high or low elasticity. While this rate of growth in public resources allocated to the agricultural sector seems unrealistically high, the resulting shares of agricultural spending are not uncommonly high based on experiences in many Asian countries in their early stages of development.

Table 11: Estimated Resource Allocation to the Agricultural Sector

	Current	CAADP target		Millennium Development Goal 1	
	(2001–06)	Low-elasticity	High-elasticity	Low-elasticity	High-elasticity
Indicator	(1)	(2)	(3)	(4)	(5)
Growth rate (%)					
AgGDP	4.2	6.2	6.2	8.8	8.8
Non-AgGDP	4.8	6.2	6.2	7.2	7.2
GDP	4.6	6.2	6.2	8.0	8.0
Agricultural spending	–6.5	30.3	15.2	45.6	22.6
Agricultural development spending	–5.8	35.9	18.4	52.3	26.8
Nonagricultural spending	11.8	6.3	6.3	7.4	7.4
Total spending	10.8	8.2	6.7	12.2	8.3
Agricultural spending/total spending (%)	4.92				
2010		6.6	4.4	9.2	5.2
2015		17.6	9.5	34.5	12.0
Agricultural spending/AgGDP (%)	3.2				
2010		4.7	3.0	6.3	3.5
2015		14.1	4.6	30.7	6.5
		2015		2015	
Nonagricultural spending/nonagGDP (%)	24.9	44.1	44.1	44.1	44.1
Total spending/GDP (%)	26.1	32.1	28.3	38.3	27.9

Source: Estimated by the authors.

C. Assessing Potential Returns to Agricultural Investment

78. Estimating the public resources needed to reach the overall agricultural growth target is important, but prioritizing investments is equally important. In order to prioritize the allocation of public investment, it is necessary to measure the returns to the investment. Public investment will generate externalities and directly and indirectly affect broad economic performance. Hence it may underestimate the impact of public agricultural investment if the gains are narrowly measured for individual sectors that directly benefit through the interventions. Moreover, as we have shown in the previous chapter, agricultural led growth is pro-poor, and the relationship between public investment in agriculture and poverty reduction needs to be taken into account when the impact of agricultural investment is assessed. In this section, we will combine the public investment analysis with the CGE model to assess the potential returns of agricultural investment from an economywide perspective.

79. As previously mentioned, constrained by the short period of existing investment data in Rwanda due to historical reasons, it is not possible to do any ex post analysis for evaluating the returns to public investment in agriculture. A more innovative approach has to be applied such that the current existing data can be used for the analysis. With help from MINAGRI we have obtained a spending plan with detailed target and costing information, prepared for the second Economic Development and Poverty Reduction Strategy (EDPRS). Based on the information received, r with other information drawn from literature, we have developed an innovative ex ante approach that is applied to organizing this information into the CGE model as inputs. We then use the CGE model to conduct a series of simulation analyses to assess the returns to public investment in the agricultural sector.

80. Table 12 summarizes the total amount of public investment in agriculture planned for 2007 – 2015, drawn from "Total Cost of EDPRS Agriculture Sector" prepared by MINAGRI (2008) and received recently from Ms. Rose Goslinga, Planning, Policy and Capacity Building Unit of MINAGRI. The original assessment of national needs to achieve the EPDRS targets is for a six-year period (2007 - 2012). To be consistent with the MDG1 timeframe we decided to consider a nine-year period (until 2015) for the analysis. Moreover, the initial assessment of the public investment required by the EDPRS targets had to be scaled down by MINAGRI due to budget constraints set by Ministry of Finance. The final agreed total spending for agriculture is about 30 percent of what had been originally planned (see second part of Table 12). However, for this analysis we decided to use the original budget allocation for the following three reasons. First, the purpose of this analysis is to provide an assessment of actual requirements in agricultural investment for achieving both the CAADP growth target and the MDG goal of halving poverty by 2015 or 2020. After assessing the growth requirement in the previous chapter of the report, it is necessary to understand the cost of such growth with a complete picture without taking into account the budget constraints. Second, our analysis considers a period of nine years between 2007 and 2015. Without scaling down the total cost planned by MINAGRI, we can slightly reduce the annual cost by allocating the same amount of total spending into nine years, instead of six years (still, the annual spending is about 50 percent higher in our analysis than that included in the EDPRS, see the annual average column of Table 12 for comparison). Third, we also consider the CAADP targets, one of which requires African countries allocate at least 10 percent of government spending to agriculture. The amount of agricultural spending, if it is based on the originally planned numbers of MINAGRI, will allow the agricultural sector to reach 10 percent of total government budget (see the last part of Table 12).[6]

[6] Seven percent of total planned public spending between 2008 and 2012 will be allocated to agriculture in EDPRS (see Table 2, second part).

Table 12: Total Accumulated Investment in Nine Years between 2007 and 2015

Agricultural spending used in the model, million RWF	9 years total	Fixed investment	Recurrent	Fertilizer + seed subsidy	Annual total average
Crop directly related	415,077	182,956	45,278	186,842	46,120
Forestry	8,641	6,742	1,899		960
Livestock	203,253	154,259	48,994		22,584
R&D, extension	26,963		26,963		2,996
Rural finance	13,662		13,662		1,518
Other investment, horticulture	122,236	90,660	31,576		13,582
Other investment, traditional export	22,840	16,940	5,900		2,538
Rural road	21,965	21,965			2,441
Ag institution	16,230		16,230		1,803
Other investment	11,265	11,263			1,252
Total	862,132	484,787	190,502	186,842	95,792
Current annual total agr. spending in million Rwf (2007)		13,517	6,434		19,951
share in total government budget		*1.4*	*7.4*		*3.9*
Proposed agr. spending, in EDPRS, 2008-2012 (5 years), million Rwf					
	242,000	158,000	84,000		48,400
share in total government budget	*7.0*	*11.5*	*4.1*		
Increase from the current annual level (times)					1.4
Amount of ag spending, if ag = 10% of total budget, annual					69,143
Compared with the number used in model, without fertilizer subsidy (model/10% budget)					1.09
Compared with the number used in model, with fertilizer subsidy (model/10% budget)					1.39

Source: Authors' calculation based on "Total Cost of EDPRS Agriculture Sector." MINAGRI (2008)

81. The key information about budget allocation and targets to be achieved through such public investment (such as how many hectares of irrigated land or how many metric tons of improved seeds will be developed) is available in the data set received from MINAGRI. Subsidy to fertilizer and improved seeds is not considered in the government budget allocation but is added as a part of public spending in the above budget allocation. As in many other African countries, the past poor performance of the agricultural sector in Rwanda is partly a consequence of the very limited use of improved seeds and fertilizers. The average application of fertilizer is only 4 – 5 kg per hectare in Rwanda, while the average level of use of improved seed is only about 1.3 percent of total seed applied. Both are below the average level for Sub-Saharan Africa (Fowler et al. 2007). With increased oil prices in the world, fertilizer prices have reached such a high level that is not affordable for the majority of small farmers in Africa. Thus, a partial subsidy on imports of fertilizer is seen as a necessary step to the increased use of fertilizer in crop production.

82. The above budget allocation information is important for any analysis to assess the economic outcome of public investment allocation; however such information alone is not enough. To assess the impact of public investment on the growth and poverty reduction ex ante, it is necessary to link the investment and its targets to the economic activities of the agricultural sector. As shown in Table A1(a) of Appendix I, the agricultural sector is composed of 16 crop subsectors, seven livestock subsectors, plus fishery and forestry. It is a big challenge to further allocate the investment into the agricultural subsectors, especially for the crop sectors, such that investment can be directly linked to the economic outcome in the

ex ante analysis. To get such detailed information at the agricultural subsector and crop level is beyond the current planning capacity of MINAGRI and we use other information to do it. Through a broad literature review, information about the current level of crop yields in the country, the unit production revenue per hectare of different crops, the achievable level of crop yields and the recommended levels of fertilizer and improved seed to achieve it, and other helpful and available information are fully utilized in the analysis. Based on such information we further allocate each type of investment into agricultural subsectors. The results of such allocation are reported in Table 13. For the investment or spending that cannot be identified sector-specifically, such as spending on agricultural R&D, extension, rural finance, agricultural institutions and so on, we decided to split them according to the ratio of total non-identified spending to the total identified spending (such as terracing, irrigation, marshland development, and fertilizer and improved seed subsidies). The last row of Table 13 reports the targeted outcome of each type of investment in hectare.

83. Obviously, growth in agricultural production at the crop or subsector level is unlikely to result from a single intervention -- many interventions have to jointly create the maximum impact. For example, without application of fertilizer and improved seeds, returns to irrigation investment are low. To capture the joint impact of different types of investments, we need to further combine different types of public investment at the agricultural subsector level. To do it, we first assume that once modern inputs are applied the level of their application will be consistent with the recommended level in order to achieve the maximum returns from such intervention. The recommended level of fertilizer is drawn from Felskens (2007). We further assume that once the crop land is irrigated, farmers will first apply fertilizer and improved seeds on such land in order to get maximum returns from such combination. With these assumptions, we can identify which intervention is a biding constraint for the combination of modern technology (inputs). As shown in Table 13, last row, the outcome of irrigation investment will be 55,000 hectares of crop area, which is the least for the four types of interventions (terracing, irrigation, and application of fertilizer and improved seeds). Thus, we decided to allocate other intervention following the allocation of irrigation area.[7]

[7] Marshland development is only for rice and some export crops (e.g., sugar cane).

Table 13: Allocation of Public Investment by Crops and Livestock Subsectors (million RWF)

	Terrace	Irrigation	Marshland	Fertilizer subsidy, 9 yr acc	Fertilizer related fixed investment	Seed subsidy, 9 yr acc	Seed related fixed investment	Total
Wheat	1,707	556		714		560		3,538
Maize	9,342	2,177		2,808		2,851		17,178
Paddy rice		1,439	50,172	5,375		12,773		69,759
Sorghum	9,031	369		1,759		2,326		13,486
Irish potatoes	9,686	1,076		48,094		2,663		61,520
Sweet potatoes	5,828	467		24,414		1,558		32,266
Cassava	6,368	483		25,743		1,695		34,289
Other roots	1,234	36		5,101		314		6,686
Pulses	11,117	157		1,292		2,790		15,356
Vegetables		3,698		14,174	45,330	23,352	45,330	131,883
Bananas	66,564	857		17,990		16,685		102,097
Fruits		1,434		2,532		355		4,320
Oil seed	7,275	510		892		1,927		10,604
Coffee		11,650		22,847	5,795	5,751	5,795	51,837
Green tea		6,408		11,565	2,675	2,910	2,675	26,233
Other export crops		228	15,858	1,542		4,243		21,872
Bovine cattle, live								71,243
Sheep and goats, live								6,938
Swine, live								4,741
Poultry, live								2,419
Raw milk								133,232
Eggs								2,481
Other livestock products								910
Fishing								4,560
Forestry								9,658
Total crops	128,153	31,545	66,031	186,842	53,800	82,754	53,800	602,925
Tot livestock								226,523
								839,106
Targeted area by 2015 (ha)	226,000	55,000	20,000	112,505		169,918		

Source: Authors' calculation based on "Total Cost of EDPRS Agriculture Sector." MINAGRI (2008)

84. The first columns of Tables 14(a) and 14(c) correspond to the allocation of irrigation area by crops in the base year (2006) and by 2015 respectively. All irrigated areas use fertilizer and improved seed, called “modern” technology in the columns. After irrigation, the second type of investment that may also result in the use of fertilizer and improved seed is terracing. We assume that farmers will also use fertilizer and improved seeds on the terraced land. The second columns of Tables 14(a) and 14(c) report the land allocation to the combination of terracing, fertilizer and improved seed by crop, and increased total amount of terraced land is consistent with investment in terracing. In the remaining columns for most crops fertilizer barely appears due to the constraints of planned government spending on the fertilizer subsidy. That is, given the currently high level of fertilizer and seed prices, we assume that without certain government supports farmers will be unlikely to increase their use of such inputs to the recommended level. Tables 14(b) and 14(d) report the share of such allocation reported in Tables 14(a) and 14(c), respectively.

85. The second to last columns of Tables 14(a) and 14(c) report the land allocation without applying any modern inputs (called “traditional”). The ratio of traditional over total land by crops is also calculated. As shown in Table 14(a), a well known fact, the use of modern input in Rwanda is very low currently. About 94 percent of land is under the traditional category in 2006, meaning no modern input was applied to such land. However, the ratio of traditional over total areas varies across crops. In general, the high value crops and rice use more modern inputs than the other crops. The last row of Table 14(d) reports the share of traditional over total land by 2015, which will decline if the planned public investment is implemented in the next nine years. As shown in the table, this ratio will fall to 76 percent by 2015, from the current 94 percent, indicating the increasing use of modern inputs in crop production through public investment. However, after nine years of investment in irrigation, the irrigated land area is still small, accounting for 4.4 percent of total crop land (the last row of Table 14(d)). Only 17.6 percent of land will be improved through terracing investment, while marshland development--mainly for growing rice and other export crops (such as sugar cane)--is about 1.7 percent of total crop areas. Through subsidies, fertilizer, if applied to the recommended level, will cover about 8 percent of land, while the application of improved seeds covers 14 percent of land. It must be noted that the actual land allocation as model result is endogenous, for which the demand side factor and change in relative prices will determine the allocation.

Table 14a: Current Land Allocation by Different Types of Investments/Spending

	Modern (irri & fert & seed)	Terrace & fert & seed	Terrace & seed	Terrace	Marshland & fert & seed	Marshland & seed	Marshland	Seed	Traditional	Total	Traditional /total
Wheat	46	28	1,482	46				82	21,287	22,972	92.7
Maize	230	481	6,870	230				399	106,627	114,836	92.9
Paddy rice	2,105				559	3,181	2,575		5,613	14,033	40.0
Sorghum	170	256	10,816	170				592	158,294	170,298	93.0
Irish potatoes	1,398	2,598	496	9,033					126,226	139,750	90.3
Sweet potatoes	139	21	4,299	2,368					131,899	138,725	95.1
Cassava	119	137	3,564	3,939					111,101	118,860	93.5
Other roots	13	6	793	418					24,021	25,251	95.1
Pulses	388	635	3,570	2,684					380,244	387,521	98.1
Vegetables	4,262								46,430	50,692	91.6
Bananas	916	533	10,323	916					353,608	366,296	96.5
Fruits	1,918								32,218	34,138	94.4
Oil seed	59	325	1,623	59					56,495	58,560	96.5
Coffee	8,523								20,239	28,762	70.4
Green tea	4,688								8,592	13,280	64.7
Other export crops	653				114	1,534	3,142		2,717	8,160	33.3
Total	25,623	5,020	43,837	19,862	673	4,715	5,717	1,075	1,585,612	1,692,134	93.7

Source: Authors' calculation based on "Total Cost of EDPRS Agriculture Sector." MINAGRI (2008)

Table 14b: Share of Current Land Allocation by Different Types of Investments/Spending

	Modern (irri & fert & seed)	Terrace & fert & seed	Terrace &seed	Terrace	Marshland & fert & seed	Marshland & seed	Marshland	Seed	Traditional
Wheat	0.2	0.1	6.5	0.2				0.4	92.7
Maize	0.2	0.4	6.0	0.2				0.3	92.9
Paddy rice	15.0				4.0	22.7	18.4		40.0
Sorghum	0.1	0.2	6.4	0.1				0.3	93.0
Irish potatoes	1.0	1.9	0.4	6.5					90.3
Sweet potatoes	0.1	0.0	3.1	1.7					95.1
Cassava	0.1	0.1	3.0	3.3					93.5
Other roots	0.1	0.0	3.1	1.7					95.1
Pulses	0.1	0.2	0.9	0.7					98.1
Vegetables	8.4								91.6
Bananas	0.3	0.1	2.8	0.3					96.5
Fruits	5.6								94.4
Oil seed	0.1	0.6	2.8	0.1					96.5
Coffee	29.6								70.4
Green tea	35.3								64.7
Other export crops	8.0				1.4	18.8	38.5		33.3
Total	1.5	0.3	2.6	1.2	0.0	0.3	0.3	0.1	93.7

Source: Authors' calculation based on "Total Cost of EDPRS Agriculture Sector." MINAGRI (2008)

Table 14c: Targeted Land Allocation by Different Types of Investments/Spending by 2015

	Modern (irri & fert & seed)	Terrace & fert & seed	Terrace & seed	Terrace	Marshland & fert & seed	Marshland & seed	Marshland	Traditional	Total	Traditional/ total
Wheat	1,014	627	2,157	1,774				19,781	25,352	78.0
Maize	4,019	3,749	14,049	6,200				97,569	125,586	77.7
Paddy rice	4,610				7,056	9,231	5,224	4,610	30,731	15.0
Sorghum	813	1,221	20,560	5,332				134,652	162,578	82.8
Irish potatoes	3,270	5,229	5,624	20,219				114,308	148,650	76.9
Sweet potatoes	951	735	6,779	9,416				128,444	146,325	87.8
Cassava	959	1,781	5,447	11,602				107,581	127,370	84.5
Other roots	76	136	1,481	1,769				25,800	29,261	88.2
Pulses	661	2,609	5,539	18,278				385,815	412,901	93.4
Vegetables	10,697							42,322	53,019	79.8
Bananas	2,408	9,784	28,042	90,923				254,119	385,276	66.0
Fruits	4,413							31,293	35,705	87.6
Oil seed	947	1,947	3,762	7,603				48,861	63,120	77.4
Coffee	28,800	19793.28							48,593	0.0
Green tea	15,840	6596.5481							22,436	0.0
Other export crops	1,049				2,033	4,368	3,193	287	10,929	2.6
Total	80,526	54,207	93,441	173,115	9,089	13,599	8,417	1,395,439	1,827,833	76.3

Source: Authors' calculation based on "Total Cost of EDPRS Agriculture Sector." MINAGRI (2008)

Table 14d: Share of Targeted Land Allocation by Different Types of Investments/Spending by 2015

	Modern (irri & fert & seed)	Terrace & fert & seed	Terrace & seed	Terrace	Marshland & fert & seed	Marshland & seed	Marshland	Traditional
Wheat	4.0	2.5	8.5	7.0				78.0
Maize	3.2	3.0	11.2	4.9				77.7
Paddy rice	15.0				23.0	30.0	17.0	15.0
Sorghum	0.5	0.8	12.6	3.3				82.8
Irish potatoes	2.2	3.5	3.8	13.6				76.9
Sweet potatoes	0.7	0.5	4.6	6.4				87.8
Cassava	0.8	1.4	4.3	9.1				84.5
Other roots	0.3	0.5	5.1	6.0				88.2
Pulses	0.2	0.6	1.3	4.4				93.4
Vegetables	20.2							79.8
Bananas	0.6	2.5	7.3	23.6				66.0
Fruits	12.4							87.6
Oil seed	1.5	3.1	6.0	12.0				77.4
Coffee	59.3	40.7						
Green tea	70.6	29.4						
Other export crops	9.6				18.6	40.0	29.2	2.6
Total	4.4	3.0	5.1	9.5	0.5	0.7	0.5	76.3

Source: Authors' calculation based on "Total Cost of EDPRS Agriculture Sector." MINAGRI (2008)

Table 15: Yield (mt/ha) by Different Types of Investments/Spending

	Modern (irri & fert & seed)	Terrace & fert & seed	Terrace &seed	Terrace	Marshland & fert & seed	Marshland & seed	Marshland	Traditional	Current average	Average yield by 2015 in base-run	Targeted average yield by 2015
Wheat	3.0	2.8	1.4	2.3	1.2	0.9	1.5	1.2	0.8	1.2	1.6
Maize	3.5	3.1	1.5	2.5	1.2	0.8	1.7	1.2	0.8	1.0	1.5
Paddy rice	6.4	5.8	5.5	5.8	6.1	4.9	6.1	5.5	3.7	4.9	4.7
Sorghum	3.4	2.7	1.7	2.4	1.5	1.1	2.1	1.5	1.1	1.5	1.7
Irish potatoes	27.2	24.9	15.5	20.2	12.6	9.2	17.0	12.6	9.1	11.9	14.7
Sweet potatoes	15.0	16.8	11.2	11.5	7.7	5.6	10.0	7.7	5.5	6.9	7.8
Cassava	27.3	24.7	11.2	18.8	8.6	6.2	12.4	8.6	6.2	8.0	10.5
Other roots	24.5	17.3	9.6	12.3	6.8	5.0	13.6	6.8	4.9	6.0	6.8
Pulses	2.7	2.4	1.2	2.1	1.1	0.8	1.4	1.1	0.8	1.0	1.0
Vegetables	29.5	19.6	14.0	19.6	14.0	10.2	21.0	14.0	9.4	7.3	9.4
Bananas	17.9	15.7	10.5	14.9	9.9	7.2	11.9	9.9	7.2	10.0	12.9
Fruits	28.6	19.1	13.6	19.1	13.6	9.9	20.5	13.6	9.7	14.3	17.1
Oil seed	2.7	1.8	1.1	1.4	0.8	0.6	1.7	0.8	0.6	0.8	1.1
Coffee	1.0	0.8	0.7	0.8	0.7	0.7	0.9	0.7	0.7	1.1	1.1
Green tea	1.7	1.4	1.2	1.4	1.2	1.2	1.5	1.2	1.1	1.7	1.7
O. export crops	45.8	38.2	27.3	38.2	32.7	23.8	32.7	27.3	17.6	26.5	35.0

Sources: Authors calculation drawn from various literatures
* Weighted by areas with different types of input/investment combination

86. With use of modern inputs, yields are expected to rise. Table 15 reports the expected yield under different combinations of modern inputs resulting from public investment or spending. A broad literature search for such information was conducted in order to define the “right yield” for different types of modern inputs and their combination. Moreover, the land allocated to different types of investments and their combinations reported in Table 14 is consistent with the yields reported in Table 15. Such levels of yield are often the results of applying modern inputs to their optimal level. For example, Table 15 shows that the yields under the “modern” technology will be quite high, e.g. maize can reach 3.5 metric ton per hectare (mt/ha) and Irish potato 27 mt/ha. While such yields seem to be at the maximum, when they are weighted by the corresponding land allocation reported in Table 14, the effect on the national average yield is quite small as only about 4.7 percent of total crop land (last row of Table 14(d)) that is expected to achieve such high levels of yield with the application of modern technology/inputs. On the other hand, more than 70 percent of crop land will still be without access to modern inputs by 2015, and yields achieved with traditional technology will still play a dominant role in determining the national average yields for most crops. As shown in the last column of Table 15, the level of yields from a majority of crops will continue to be low by 2015, even after significantly increased public investment in agriculture. For example, the average level of maize yield at the country level is expected to be only around 1.5 metric mt/ha by 2015, although it is possible to have a yield of 3.5 mt/ha with combination of irrigation, fertilizer and seed uses (first column of Table 15). While it is a significant increase from the current level of maize yield at 0.8 mt/ha, it is still lower than the level of maize yield that many Sub-Saharan African countries have already achieved. To compare the current level of yield and possible yields by 2015 under a business as usual assumption, we report in the last three columns of Table 15 three different levels of national average yields. The yield level reported in the “current average” column of Table 15 is consistent with the base-year yields applied in the model, while the numbers in the Table 15 column called “yield by 2015 in base-run” is consistent with those in Table 5(a), and the numbers reported in the last column of Table 15 can be understood as the targeted average yield by 2015, the expected results with all planned public investment implemented.

87. Targeted crop average yields and the outcome of public investment in livestock and roads are applied in the CGE model as exogenous shocks to the land productivity (in the case of crop production) or total factor productivity (in the case of livestock production, trade, transportation and communication sectors). Ideally, the CGE model should consider all these different types of technologies to endogenously capture the productivity growth at the national level as a result of technology shifting from low to high yields. However, constrained by a lack of such information at the district level and between different types of farm groups (the production functions are defined at the district level for small, and medium and large farm groups in the model), we are unable to capture the endogenous productivity growth in the analysis. Instead, we have to apply the exogenous productivity shocks calculated from the potential growth in the yields as results of public investments and use of modern inputs. With such exogenous shocks, the CGE model generates a series of results that are in general consistent with the planned public investment and its targets. Because of this, we do not need to report the model results of crop yield again.

Table 16: Land Allocation as CGE Model Results of Investment Scenario (1000 ha)

		by 2015	
	Current level	Base-run	Simulation with investment
Wheat	23	25	25
Maize	115	126	126
Paddy rice	14	18	30
Sorghum	170	162	164

Irish potatoes	140	149	154
Sweet potatoes	139	136	123
Cassava	119	123	111
Other roots	25	29	30
Pulses	388	410	428
Vegetables	51	51	51
Bananas	366	393	394
Fruits	34	32	33
Oil seed	59	61	60
Coffee	29	34	45
Green tea	13	16	24
Other export crops	8	9	12
Total	1,692	1,775	1,809

Sources: CGE model results

88. Table 16 reports the land allocation as model results of the investment scenario. As shown in Table 16, it is not necessary to increase land areas for all crops. For example, the current area of sorghum is about 170 thousand hectares (ha), and it falls to 162 ha in the base-run and slightly increases to 164 thousand ha in the investment scenario. Similarly, the area harvested for sweet potatoes falls to 123 thousand ha in the investment scenario, from current of 139 thousand ha. Such declines are the endogenous results of the model due to both relatively lower productivity growth and demand side constraints. On the other hand, areas increase in many other crops, particularly for high value crops such as coffee, and high demanded crops such as rice. The result of increase in total land from the baseline is thus due to increased land for rice and some high value crops as results of irrigation and marshland development investment.

Table 17: Agricultural Subsector Annual Growth Rate as CGE Model Results of Investment Scenario

	Base-run	Simulation with investment
Wheat	4.9	8.5
Maize	3.9	8.2
Paddy rice	3.9	9.7
Sorghum	3.1	4.2
Irish potatoes	3.6	6.5
Sweet potatoes	2.1	2.4
Cassava	3.2	5.2
Other roots	3.9	5.7
Pulses	3.4	4.6
Vegetables	4.4	7.5
Bananas	3.7	6.6
Fruits	3.5	5.4
Oil seed	3.7	6.6
Coffee	6.3	9.8
Green tea	6.1	10.5
Other export crops	4.5	10.1

Cattle	4.2	7.4
Sheep and goats	4.5	9.6
Swine	3.8	7.5
Poultry	4.6	11.8
Raw milk	7.3	17.8
Eggs	7.5	18.0
Other livestock	7.0	18.8
Forestry	3.8	6.5
Fishing	4.8	8.9

Sources: CGE model results

89. With such land allocation, together with the increases in yield reported in Table 15, the subsector level of agricultural growth is reported in Table 17, while the aggregate growth in the economy, as a whole and in aggregate economic sectors, is reported in Table 18. The growth results in the second column of Table 17, obtained under the investment scenario, are comparable with those in Tables 7a and 7b for 2015 under the agricultural growth scenario (Scenario 20), and similar growth rates in land productivity are obtained under the two scenarios: one with growth target consideration only, and the other with investments to support such targets. Moreover, as shown in the second row of Table 18, increased public investment, if it is implemented as planned, is able to support more than 6 percent agricultural annual growth in the next 9 years, which is a similar growth rate obtained under the agricultural growth scenario (Scenario 20). Livestock will have the highest growth rate, more than doubling the current annual growth rate. Among crops, export crops benefit more from increased investment, with annual growth reaching 7.9 percent, followed by the grain sector, at 7.0 percent annual growth. While agricultural investment will not directly go to the nonagricultural sectors, the food processing sectors will benefit indirectly from such investment. Investment in roads will improve productivity in trade, transport and communication sectors, which in turn will help growth in the agricultural sector.

Table 18: Annual Growth in Aggregated Economic Sectors and GDP as CGE Model Results of Investment Scenario

	Base-run	Simulation with investment
GDP	4.8	6.0
AgGDP	3.8	6.5
Grains	3.6	7.0
Root crops	3.1	5.1
Other food	4.1	6.5
Cash and exportables	4.7	7.9
Livestock	5.5	12.6
Fish and forestry	4.0	6.9
Industry	5.1	5.1
Processing manufacturing	6.2	7.9
Coffee processing	8.3	11.8
Tea processing	6.7	10.6
Services	5.7	5.8
Trade	4.4	6.2

Transport	7.0	6.5
Communication	8.0	6.4

Sources: CGE model results

90. Table 19 reports the poverty impact of public investment. Through its linkages with growth, poverty falls more in the rural areas. As we discussed before, the calculated poverty-to-growth elasticity shows that staple-led agricultural growth is more pro-poor: one percent additional growth in the economy led by staple crop productivity growth results in 1.4 – 2.4 percent poverty reduction. While the 36.2 percent poverty rate in 2015 is still higher than the MDG1 target,[8]the distance is not unreachable. As we mentioned in the previous chapter, with additional growth from the nonagricultural sector, the country will be able to achieve MDG1 by 2020.

Table 19: Poverty Rate as CGE Model Results of Investment Scenario

		2015	
	Current level	Base-run	Simulation with investment
National	57.6	46.7	37.2
Urban	28.8	27.9	19.9
Rural	63.4	50.4	40.7

Sources: CGE model results

91. We also calculate the dollar-to-dollar returns of public investment in agriculture. Such returns are measured by increased GDP and AgGDP, both in real terms (i.e., in the base year prices). To do this, we also consider future returns after 2015 from additional investment occurring in the next nine years. To calculate such future returns, we apply a 10 percent time discount rate and choose a very long time period, such that for a given amount of public investment, together with the recurrent spending, the returns are eventually discounted to close to zero in a longer enough period of time (e.g., 20 – 30 years). We included spending related to fertilizer and seed subsidies in the recurrent spending, which is also discounted with the same 10 percent time discount rate for the same time period. As mentioned earlier, returns to public funds invested in a specific sector should not be measured narrowly by the benefits of this sector. With their public good characteristics, public investments often generate strong and positive externalities in the economy, such as technological spillovers within agriculture, and growth linkages between agricultural and nonagricultural activities. Thus, increases in GDP are used to measure the returns to agricultural investment in Table 20, allowing us to fully capture the economywide gains of public investment in agriculture.

92. It is also necessary to measure the economywide returns as results of public funds invested in a specific agricultural subsector in order to understand which sector is more efficient in investment. For this purpose, we designed 21 more model scenarios (Scenarios I-1 to I-21), each focused on the investment going to a specific sector. For example, first row of Table 20 is the result of public funds invested in maize production. In this scenario we assume that only productivity growth in maize production is the direct outcome of increased investment, holding productivity growth in all other sectors at their base-run level. Similarly, in the second row of Table 20, we assume that only productivity growth in rice production comes directly from public investment. We also consider the productivity growth for a group of commodities, such as grains, root crops and so on, as the results of public investment. For the row named “grains”, the result is from a scenario in which public investment directly results in the increase of yield in grain production, including maize, rice, wheat, and sorghum, while productivity growth in the other sectors is the same as in the base-run. In the last two rows of Table 20 there are results from the two

[8] National poverty rate was 60.3 percent in 1999 (EICV1 for 1999-2001). If this poverty rate is targeted to be halved by 2015, it requires poverty rate fall to 30 percent by 2015.

scenarios considering broad investment in all agricultural subsectors. In Scenario I-20 (the second row from the bottom of Table 20) productivity growth in staple crops and livestock is the result of public investment holding productivity growth in export crops at the base-run level, while in scenario I-21 (the last row of table 20) agricultural investment in all subsectors is considered.

Table 20: Returns to Public Investment by Agricultural Subsectors

	GDP/investment	AgGDP/investment
Maize	6.59	7.02
Paddy rice	1.22	1.41
Wheat	5.34	5.15
Cassava	5.46	4.61
Irish potatoes	5.88	5.66
Sweet potatoes	2.53	2.22
Pulses	9.09	8.21
Bananas	5.35	4.94
Oil seed	5.89	4.73
Coffee	1.01	1.74
Green tea	1.95	2.52
Other cash and export crops	1.07	1.08
Poultry	10.54	10.09
Other livestock	1.81	1.74
Fishing	12.50	12.35
Grains	2.73	2.75
Root crops	5.03	4.65
Cash and export crops	1.02	1.24
Livestock	2.02	1.90
Staple crops and livestock	3.84	3.63
Agriculture total	3.19	3.11

Sources: CGE model results

93. The first column of Table 20 calculates the generation of increases in GDP for each thousand dollars (or one million Rwf) of increased public funding invested in the agricultural sector or a subsector of agriculture. In the second column of Table 20, we report the ratio of increased AgGDP to investment. As shown in the last two rows of Table 20, economywide returns to public investment in overall agriculture are about 3.1-to-1, and are 3.6-to-1 from investing in staple production (including both staple crops and livestock). We also notice that the returns to the investment measured as increased GDP are higher than those measured as increased AgGDP for a same amount of public spending in agriculture. These results further indicate the importance of fully measuring the economywide returns of agricultural investment as agricultural investment, also indirectly benefits the nonagricultural sectors through production linkages (such as using agricultural materials as inputs in agro-processing or increased demand for trade and transports after more agricultural products going to the markets) and consumption linkages (because of increased farmers' demand for nonagricultural goods with increased their incomes).

94. At the aggregated subsector group level (second part of Table 20), returns to investment in root crops are highest, measured either as increased GDP or AgGDP. Returns to investment in grain production rank second, while returns to investment in export crops are the lowest, but are still more than one. The first part of Table 20 reports economywide returns from investment in each individual agricultural production. For all agricultural sectors, returns to investment, measured by increased GDP,

are greater than the cost of the investment, as all the numbers are greater than one and many are greater than two or three. However, in the case of coffee, returns to investment, measured by increased GDP, are the lowest, at 1.01-1. On the other hand, measured directly by increased AgGDP, coffee investment is quite profitable, as one dollar's investment results in 1.74 dollars increased in AgGDP overtime. That the increased GDP is significantly less than the increased AgGDP indicates the weak linkage of the coffee sector with the rest of economy. Coffee is mainly for export purposes and coffee processing is primarily dominated by a simple process. Without increasing the value addition of coffee production, the sector is unlikely to create strong linkages and multiplier effects in the economy. Moreover, export-led growth can have certain macroeconomic effect on the real exchange rate. For example, if growth in exports of primary products, including primary processed agricultural products such as coffee and tea, is too high, it may create a certain Dutch disease impact to raise the real exchange rate in the country. An appreciated exchange rate could in turn raise the cost for other exportable sectors and make them more difficult to export. An appreciated exchange rate causes imports to become cheaper and thus import-competitive sectors become unable to compete. This is the other important factor explaining why returns to investment in coffee, measured by increases in GDP, are so low.

7. CONCLUSIONS

95. The agricultural development strategies put forward by individual African countries under the Comprehensive Africa Agricultural Development Programme (CAADP) delineate priorities for actions to enhance agricultural and overall development. Understanding alternative agricultural growth options and their linkages with poverty reduction, and prioritizing agricultural investments are the two key components of an agricultural development strategy based on assessments of national needs. However, the relationships between growth and poverty reduction and between targeted growth and required public investment are not straight forward and solid research is necessary in order to support evidence-based policymaking. This report provides such a study, using Rwanda as a case. An economywide model was developed for the study and this model was applied to the most recent economic data and public investment information to analyze the agricultural growth and investment options for poverty reduction in Rwanda. The reports focuses on analyzing the linkages and trade-offs between growth and poverty reduction goals at both the macro- and micro-economic levels, and tries to provide answers to three policy-related questions: (1) What are the most effective pro-poor agricultural growth strategies? (2) How can the important linkages between agriculture and nonagriculture be strengthened such that non-farm activities will become an important source of income for both growth and poverty reduction? (3) What are the most cost effective public investment choices for stimulating shared growth and poverty reduction? The following main findings of this report seem to be helpful for answering these questions.

A. Six Percent Annual Growth of CAADP Goal Is Not Only Necessary but Also Achievable

96. The model simulations indicate that the country's targeted agricultural subsector growth, if achieved, would allow Rwanda to meet the CAADP target of 6 percent AgGDP growth from 2008 to 2015. With comparable growth in the nonagricultural sector, the agricultural growth would increase to 6.5 percent and total GDP growth to 7.4 percent, as a result of economywide interlinkages. Such growth would cause the national poverty rate to fall to 35.5 percent by 2015, a reduction of 24.8 percentage points over the 1999 rate. If this level of growth continues until 2020, Rwanda would be able to achieve the Millennium Development Goal of halving the national poverty rate by 2020, a target included in the country's EDPRS.

B. Subsector Level Growth Matters

97. The majority of rural households benefit from rapid agricultural growth, and the distribution of such benefits is comparatively equal. However, the most vulnerable households—those with very small landholdings and with few opportunities to participate in the production of cash crops—appear to benefit less.

98. An analysis of the poverty–growth elasticity shows that 1 percent growth in per capita GDP, driven by agriculture, has much greater poverty-reduction effect than the same level of growth driven by the nonagricultural sector. Among agricultural subsectors, the growth driven mainly by increased staple crops has the greatest poverty-reduction effect. Agricultural households with greater opportunities to produce high-value export products are better positioned to benefit from export agriculture. But these households are usually not as poor as other more remote households, so export-led growth may have less impact in reducing poverty.

99. Cereals, especially rice and maize, are among the high priorities for the government; accordingly, they have very high growth targets. If these growth targets are reached, cereals would become the most important source of income growth for many rural households, especially for those with the smallest landholding. Growth in cereals would also help the country reduce its dependence on imports. While both maize and rice will continue to depend on imports, ratio of imports to domestic consumption will significantly fall by 2015.

100. High growth in both traditional and nontraditional agricultural exports would significantly increase agricultural trade surpluses. The projected agricultural trade surplus would be about 29 percent of the nonagricultural trade deficit, more than three times the current ratio.

101. The study also warns of possible price declines in some commodities with very high growth targets. Unbalanced growth does not always benefit producers if it is concentrated in a few subsectors. As the targeted growth rates for some livestock products such as poultry and raw milk are very high, a negative price effect could result if production growth is out of balance with income growth. Simulations indicate that with an annual growth in poultry production of more than 9 percent and raw milk more than 15 percent during 2007-15, prices for these two commodities will decline 35 to 40 percent, even though their demand is highly income-elastic.

C. Agricultural Spending Needs to Increase Substantially

102. Meeting the CAADP six percent agricultural growth target will require the allocation of public resources to the agricultural sector to rise by between 10 and 17.6 percent of total spending by 2015, depending on efficiency in spending. This level of allocation translates, in real terms, as 15 to 30 percent annual growth in agricultural spending over the next nine years. Given that agriculture needs to grow at 6.5 percent over the period of 14 to 15 years to meet the goal of halving the national poverty rate by 2020, more rapid growth in agricultural spending between 2008 and 2015 is required. The original cost estimation prepared by MINAGRI (2007) without scaling down is about 10 percent of the total government budget by 2015, which is not only consistent with the CAADP target, but also is able to support agricultural growth to achieve more than six percent annual growth, helping the country meet the target set by CAADP and MDG1.

D. Economywide Returns to Public Investment in Agriculture Are High

103. Measured as increased GDP overtime, the economywide returns to agricultural investment are 3.2 thousand dollars for each thousand dollar’s spending. Such gains also come from growth in the

nonagricultural sector as a result of multiplier and linkage effects between agriculture and nonagriculture. Comparing increased GDP with increased AgGDP as the outcomes of one dollar of additional public investment in agricultural staples, we see that increased GDP is 0.21 dollar more than increased AgGDP, indicating growth in the nonagricultural sector stimulated by growth in the staple agricultural sector.

E. Investing in Staple Crops Has the Highest Economywide Returns

104. Economywide returns to public investment in staple crop production are the highest. This is particularly true in root crop-related spending. Such results make sense, given that both current yields and use of modern inputs are extremely low for most grain and root crops (except for rice) in Rwanda, even compared to other Sub-Saharan African countries. The high returns are also the result of a linkage effect, particularly for root crops, as productivity growth in such crops lowers pressure on land expansion, reduces food prices for poor consumers, and creates more growth opportunities in the other agricultural and nonagricultural sectors. While returns to investments in staple crops are high, the planned amount of investment will not be enough to significantly improve the low yield situation for many crops nationwide in the next nine years. The average yield for maize will be as low as 1.5 metric ton per hectare by 2015, a level many African countries have currently reached.

F. Trade-Offs between Growth and Investment Returns for Export Crops

105. While investment in export crops has the highest impact on growth in these subsectors, the economywide returns are quite low. The growth rate of coffee and tea can reach double-digits with targeted investment to the export sector, measured by increased GDP over time; however, such investment has lowest returns, particularly in the case of coffee. The reason for these low-returns is mainly due to the weak linkages with other economic activities both on the production and consumption sides. While it is possible to strengthen such linkage effects in the export sector by promoting agro-processing with high value addition, because of weak income-to-consumption linkages, the same amount of public investment to the export sector will unlikely become a dominant driver in both overall economic growth and poverty reduction.

106. The export sector has often attracted more government attention among many African countries. With favorable policies and investment support, government spending to promote the export sector represents a much higher share of total agricultural spending, compared to the size of the export sector in the total agriculture economy. The findings of this report show relatively low economywide returns to public spending in the export sector, and relatively less poverty reduction from growth led by promoting exports, further indicating the importance of broad-based agricultural growth. Agricultural development strategy, including an effective public investment strategy, must focus on growth in which a majority of farmers can participate. Only such a strategy can be expected to be efficient and effective in growth and poverty reduction, as well as in the economic development of the country in general.

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9. APPENDIX I: ECONOMY AND HOUSEHOLD DEMAND STRCUTRUE

Table A1 (a): Rwanda's economic structure – agriculture

	Share in GDP	Share in employment	Share in exports	Export-output ratio	Share in imports	Import-absorption ratio
Wheat	0.22	0.12			0.34	21.26
Maize	1.34	0.69			1.77	22.42
Paddy rice	0.79	0.39			2.79	36.38
Sorghum	1.77	0.95				
Irish potatoes	7.12	3.74	0.85	0.40		
Sweet potatoes	4.86	2.54				
Cassava	3.52	1.88				
Other roots	0.97	0.52				
Pulses	4.77	2.48				
Vegetables	0.99	0.64	0.18	0.62		
Bananas	8.04	4.30	0.01	0.01		
Fruits	1.09	0.71	0.05	0.15		
Oil seed	0.74	0.39				
Coffee	0.95	0.71				
Green tea	0.53	0.33				
Other export crops	0.41	0.19	0.41	4.13	0.02	1.10
Cattle	0.91	1.35				
Sheep and goats	0.12	0.18				
Swine	0.08	0.12				
Poultry	0.10	0.14				
Raw milk	0.53	0.79				
Eggs	0.09	0.13				
Other livestock	0.10	0.15	1.44	61.79		
Forestry	2.65	3.63				
Fishing	0.41	0.60				

Source: Rwanda social accounting matrix (2006)

Table A1 (b): Rwanda's economic structure – non-agriculture

	Share in GDP	Share in employment	Share in exports	Export-output ratio	Share in imports	Import-absorption ratio
Mining	0.78	0.85	23.74	100.00		
Meat, fish and dairy products	0.32	0.34	0.16	0.24	0.03	0.31
Processed cereals	0.36	0.44	0.03	0.08	4.36	43.20
Coffee processing	0.58	0.48	30.51	78.67		
Tea processing	0.63	0.52	33.19	76.92		
Other processing	0.08	0.09			9.24	86.58
Traditional beverages	1.14	1.37				
Modern beverages	0.62	0.55	0.26	0.52	0.44	7.00
Tobacco	0.22	0.13	0.04	0.39	0.51	26.85
Textile and clothing	0.31	0.44	0.20	0.79	7.86	71.46
Wood, paper and printing	0.24	0.21	0.07	0.47	3.57	62.87
Chemicals	0.48	0.21	1.65	4.87	28.07	84.12
Non-metal minerals	0.64	0.30	0.23	0.69	2.61	35.10
Other manufacturing	0.81	0.54	6.99	20.47	38.40	88.03
Electricity, gas and water	0.64	0.53				
Construction	6.60	8.50				
Wholesale and retail	9.24	11.13				
Hotels and restaurants	0.82	0.93				
Transports	3.53	4.80				
Communication	2.25	2.08				
Finance and insurance	5.07	6.94				
Real estate	6.11	2.11				
Business services	1.79	2.22				
Repair	0.66	0.59				
Public administration	6.37	14.37				
Education	4.26	7.47				
Health	1.38	2.21				
Other personal services	0.98	1.95				
Agriculture	43.10	27.70	2.94	0.27	4.91	2.00
Non-agriculture	56.90	72.30	97.06	4.25	95.09	21.51
Industry	14.45	15.50				
Manufacturing	6.43	5.62				
Other industry	8.02	9.88				
Services	42.45	56.80				
Total	100.00	100.00	100.00	2.97	100.00	15.75

Source: Rwanda social accounting matrix (2006)

Table A2. Per capita total expenditure and average budget share (ABS) by major commodities, 1999-2001

EICV 1	Quintile	Total expenditure pc	Maize	Rice	Sorghum	Wheat	Cassava	Potato	Sweet potato
Rural	Lowest	15,428	5.2	0.7	3.5	0.3	8.3	7.6	16.8
	Second	27,104	4.5	0.7	3.0	0.4	6.9	7.9	19.0
	Third	38,438	4.6	1.1	3.1	0.3	6.2	7.6	17.5
	Fourth	54,633	4.1	1.4	3.1	0.4	5.3	6.3	14.1
	Highest	102,759	2.5	2.4	2.2	0.8	3.4	4.8	8.5
	Rural total	46,016	3.8	1.5	2.8	0.5	5.3	6.4	13.8
Urban	Lowest	14,802	1.3	1.4	2.2	0.3	6.6	12.6	7.4
	Second	29,324	1.2	4.8	2.4	0.5	4.8	9.5	5.3
	Third	40,806	1.5	5.8	1.5	0.7	6.3	9.5	4.6
	Fourth	58,727	1.1	4.6	1.7	1.1	5.0	7.1	3.0
	Highest	204,151	0.6	4.0	0.7	2.0	1.7	3.1	0.7
	Urban total	165,276	0.6	4.1	0.8	1.9	2.0	3.5	1.0
National total		57,824	2.9	2.2	2.3	0.9	4.4	5.6	10.2

Table A2. Continue

EICV 1	Quintile	O. roots	Pulses	Banana	Vegetable	Fruits	Oilseeds	O. crops	Livestock	Processed food	Nonfood
Rural	Lowest	2.3	14.8	2.1	12.8	3.6	2.4	0.4	1.7	3.3	14.2
	Second	2.8	14.3	3.5	10.3	2.6	2.7	0.6	1.9	4.0	14.9
	Third	2.9	12.5	4.3	8.5	2.7	3.0	0.9	2.5	5.0	17.3
	Fourth	3.4	11.4	4.8	6.6	2.1	3.4	1.3	4.0	5.6	22.7
	Highest	2.0	7.3	5.9	5.5	2.1	3.5	2.3	6.4	8.0	32.6
	Rural total	2.7	10.9	4.7	7.6	2.4	3.2	1.4	4.0	5.9	23.2
Urban	Lowest	0.5	11.4	0.5	5.7	2.5	3.9	3.2	2.2	3.7	34.6
	Second	0.3	8.5	3.0	10.1	1.8	4.1	5.1	5.4	3.1	30.3
	Third	0.5	8.6	2.3	6.5	1.4	4.2	4.6	4.5	3.2	34.1
	Fourth	0.4	5.4	2.8	7.0	2.4	4.5	5.0	7.3	3.6	38.0
	Highest	0.1	2.2	2.3	5.5	1.3	3.8	3.6	9.4	4.5	54.5
	Urban total	0.2	2.6	2.3	5.6	1.3	3.9	3.7	9.1	4.4	52.8
National total		2.0	8.6	4.0	7.0	2.1	3.4	2.0	5.5	5.5	31.5

Sources: Authors' calculation using EICV1 data

Table A3. Per capita total expenditure and average budget share (ABS) by major commodities, 2005-06

EICV 2	Quintile	Total expenditure pc	Maize	Rice	Sorghum	Wheat	Cassava	Potato	Sweet potato
Rural	Lowest	30,724	3.8	0.6	1.7	0.1	6.6	6.2	17.3
	Second	51,390	3.4	1.1	2.4	0.3	7.3	7.2	12.6
	Third	71,727	4.1	1.3	2.5	0.1	5.9	7.0	10.2
	Fourth	104,948	3.2	1.5	2.1	0.2	4.9	5.8	8.0
	Highest	230,150	3.4	2.1	1.9	0.1	2.9	4.4	6.3
	Rural total	90,039	3.5	1.6	2.1	0.1	4.8	5.7	9.2
Urban	Lowest	28,713	3.9	1.0	1.2	0.0	8.1	6.4	10.1
	Second	50,860	4.7	1.6	2.2	0.2	9.5	5.1	7.0
	Third	68,603	4.1	1.7	2.0	0.0	8.4	6.1	6.0
	Fourth	106,318	3.4	2.8	1.7	0.0	6.3	5.9	4.7
	Highest	361,480	1.0	3.2	0.5	0.1	1.7	2.9	0.9
	Urban total	229,310	1.4	3.0	0.7	0.1	2.5	3.4	1.7
National total		112,942	2.8	2.1	1.6	0.1	4.1	4.9	6.7

Table A3. Continue

EICV 2	Quintile	O. roots	Pulses	Banana	Vegetable	Fruits	Oilseeds	O. crops	Livestock	Processed food	Nonfood
Rural	Lowest	0.8	18.5	6.2	4.5	0.9	2.4	0.3	1.3	4.8	24.1
	Second	0.7	16.4	5.9	4.0	0.9	2.6	0.6	2.3	6.0	26.3
	Third	0.8	14.7	6.5	3.9	1.0	2.9	0.7	3.0	7.2	28.1
	Fourth	0.9	12.0	8.2	3.8	0.9	3.1	1.1	3.7	8.2	32.3
	Highest	0.3	9.6	6.8	3.2	0.8	3.2	1.5	5.0	9.5	38.8
	Rural total	0.6	12.8	6.9	3.7	0.9	3.0	1.1	3.7	7.9	32.4
Urban	Lowest	0.1	14.4	3.2	5.5	1.0	3.7	0.5	2.4	5.1	33.3
	Second	0.4	14.3	3.8	5.3	1.0	3.5	1.3	2.8	5.3	32.0
	Third	0.3	12.7	4.8	4.9	1.1	3.4	2.1	4.0	6.8	32.0
	Fourth	0.3	8.2	4.8	4.3	1.0	3.5	2.4	4.8	7.7	38.0
	Highest	0.1	2.5	2.2	3.0	0.8	2.5	2.4	7.3	7.7	61.3
	Urban total	0.1	3.8	2.5	3.3	0.9	2.6	2.3	6.8	7.6	57.2
National total		0.5	9.7	5.5	3.6	0.9	2.9	1.5	4.7	7.8	40.7

Sources: Authors' calculation using EICV2 data

Table A4. Marginal budget share (MBS) by major commodities, 1999-2001

EICV 1	Quintile	Maize	Rice	Sorghum	Wheat	Cassava	Potato	Sweet potato	O. roots
Rural	Lowest	2.3	8.0	2.3	2.4	3.5	6.4	3.7	1.4
	Second	1.7	6.8	1.8	2.3	2.8	5.2	2.5	1.0
	Third	1.4	6.1	1.5	2.3	2.4	4.4	1.8	0.8
	Fourth	1.0	5.4	1.2	2.2	1.9	3.8	1.2	0.6
	Highest	0.5	4.3	0.7	2.1	1.2	2.6	0.1	0.2
	Rural total	1.4	6.2	1.5	2.3	2.4	4.5	1.9	0.8
Urban	Lowest	2.5	8.3	2.4	2.5	3.7	6.7	4.0	1.5
	Second	1.7	6.7	1.7	2.3	2.7	5.0	2.4	1.0
	Third	1.3	6.0	1.4	2.2	2.3	4.4	1.8	0.8
	Fourth	1.0	5.3	1.1	2.2	1.9	3.6	1.1	0.5
	Highest	-0.1	3.1	0.2	2.0	0.5	1.5	-1.0	-0.1
	Urban total	0.2	3.8	0.5	2.0	1.0	2.1	-0.3	0.1
National total		1.3	5.9	1.4	2.2	2.3	4.3	1.7	0.7

Table A4. Continue

EICV 1	Quintile	Pulses	Banana	Vegetable	Fruits	Oilseeds	O. crops	Livestock	Processed food	Nonfood
Rural	Lowest	5.4	6.4	6.6	1.6	7.1	5.8	13.8	8.1	15.1
	Second	4.1	5.2	5.8	1.4	6.1	5.1	12.7	7.2	28.3
	Third	3.4	4.6	5.4	1.4	5.5	4.7	12.1	6.7	35.7
	Fourth	2.7	4.0	5.0	1.3	4.9	4.2	11.5	6.2	43.0
	Highest	1.5	3.0	4.3	1.2	4.0	3.5	10.5	5.3	55.1
	Rural total	3.4	4.7	5.5	1.4	5.5	4.7	12.1	6.7	35.0
Urban	Lowest	5.7	6.6	6.8	1.6	7.3	6.0	14.0	8.3	12.1
	Second	4.0	5.1	5.8	1.4	6.0	5.0	12.6	7.1	29.4
	Third	3.3	4.5	5.4	1.3	5.4	4.6	12.0	6.6	36.7
	Fourth	2.5	3.9	4.9	1.3	4.8	4.2	11.4	6.1	44.3
	Highest	0.3	1.9	3.6	1.0	3.0	2.9	9.5	4.5	67.1
	Urban total	1.0	2.5	4.0	1.1	3.6	3.3	10.1	5.0	60.1
National total		3.2	4.5	5.3	1.3	5.3	4.6	11.9	6.5	37.5

Sources: Authors’ estimation using EICV1 data

Table A5. Marginal budget share (MBS) by major commodities, 2005-06

EICV 2	Quintile	Maize	Rice	Sorghum	Wheat	Cassava	Potato	Sweet potato	O. roots
Rural	Lowest	3.1	5.7	1.5	0.1	2.1	4.7	2.8	0.3
	Second	2.6	4.9	1.2	0.1	1.7	4.0	2.4	0.2
	Third	2.3	4.5	1.0	0.1	1.5	3.6	2.2	0.2
	Fourth	2.0	4.0	0.9	0.1	1.3	3.2	2.0	0.1
	Highest	1.4	3.2	0.6	0.1	0.8	2.4	1.5	0.1
	Rural total	2.3	4.5	1.1	0.1	1.5	3.6	2.2	0.2
Urban	Lowest	3.1	5.7	1.5	0.1	2.1	4.7	2.8	0.3
	Second	2.6	5.0	1.2	0.1	1.7	4.0	2.4	0.2
	Third	2.3	4.6	1.1	0.1	1.5	3.7	2.2	0.2
	Fourth	2.0	4.0	0.9	0.1	1.3	3.2	1.9	0.1
	Highest	1.1	2.7	0.4	0.1	0.6	2.0	1.3	0.1
	Urban total	1.7	3.6	0.7	0.1	1.0	2.8	1.7	0.1
National total		2.2	4.4	1.0	0.1	1.4	3.5	2.1	0.2

Table A5. Continue

EICV 2	Quintile	Pulses	Banana	Vegetable	Fruits	Oilseeds	O. crops	Livestock	Processed food	Nonfood
Rural	Lowest	5.7	6.7	5.2	1.4	4.4	4.1	13.2	12.5	26.6
	Second	4.8	5.6	4.6	1.2	3.8	3.6	11.8	11.3	36.1
	Third	4.3	5.0	4.2	1.1	3.5	3.2	10.9	10.6	41.7
	Fourth	3.7	4.3	3.8	1.0	3.1	2.9	10.0	9.8	47.9
	Highest	2.7	3.0	3.1	0.9	2.3	2.2	8.4	8.5	58.8
	Rural total	4.3	5.0	4.2	1.2	3.5	3.3	11.0	10.7	41.3
Urban	Lowest	5.7	6.7	5.2	1.4	4.5	4.1	13.2	12.5	26.4
	Second	4.8	5.6	4.6	1.2	3.8	3.6	11.8	11.3	35.9
	Third	4.4	5.0	4.2	1.2	3.5	3.3	11.0	10.7	41.1
	Fourth	3.7	4.2	3.8	1.0	3.0	2.9	10.0	9.8	48.1
	Highest	2.2	2.4	2.7	0.8	2.0	1.9	7.6	7.8	64.4
	Urban total	3.2	3.6	3.4	1.0	2.7	2.5	9.2	9.1	53.5
National total		4.2	4.8	4.1	1.1	3.4	3.1	10.7	10.4	43.3

Sources: Authors’ estimation using EICV2 data

10. APPENDIX II: MATHEMATIC PRESENTATION OF THE DCGE MODEL

II.1(a) CGE model sets and parameters

Symbol	Explanation	Symbol	Explanation
Sets			
$a \in A$	Activities	$c \in CT(\subset C)$	Transaction service commodities
$a \in ALEO(\subset A)$	Activities with a Leontief function at the top of the technology nest	$c \in CX(\subset C)$	Commodities with domestic production
$c \in C$	Commodities	$f \in F$	Factors
$c \in CD(\subset C)$	Commodities with domestic sales of domestic output	$i \in INS$	Institutions (domestic and rest of world)
$c \in CDN(\subset C)$	Commodities not in *CD*	$i \in INSD(\subset INS)$	Domestic institutions
$c \in CE(\subset C)$	Exported commodities	$i \in INSDNG(\subset INSD)$	Domestic non-government institutions
$c \in CEN(\subset C)$	Commodities not in *CE*	$r \in R$	Subnational regions (provinces)
$c \in CM(\subset C)$	Aggregate imported commodities	$z \in Z$	Districts or zones within a region
$c \in CMN(\subset C)$	Commodities not in *CM*	$h \in H(\subset INSDNG)$	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' $\in$ INSDNG'; i $\in$ 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
		$trnsfr_{i\,f}$	Transfer from factor f to institution i

II.1(b) CGE model elasticities, coefficients and exogenous variables

Symbol	Explanation	Symbol	Explanation
Greek Symbols (elasticities and shift coefficients)			
α_a^a	Efficiency parameter in the CES activity function	δ_{cr}^t	CET function share parameter
α_a^{va}	Efficiency parameter in the CES value-added function	δ_{fa}^{va}	CES value-added function share parameter for factor *f* in activity *a*
α_c^{ac}	Shift parameter for 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_{cr}^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		
pwe_c	Export price (foreign currency)	pwm_c	Import price (foreign currency)

II.1(c) CGE model endogenous variables

Symbol	Explanation	Symbol	Explanation
Endogenous Variables Continued			
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
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
$GSAV$	Government savings	QM_{cr}	Quantity of imports of commodity c
QF_{fa}	Quantity of factor demand		
MPS_{i}	Marginal propensity to save for domestic non-government institution (exogenous variable)	QQ_{c}	Quantity of goods supplied to domestic market (composite supply)
PA_{a}	Activity price (unit gross revenue)	QT_{c}	Quantity of commodity demanded as trade input
PDD_{c}	Demand price for commodity produced and sold domestically	QVA_{a}	Quantity of (aggregate) value-added
PDS_{c}	Supply price for commodity produced and sold domestically	QX_{c}	Aggregated quantity of domestic output of commodity
PE_{cr}	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_{cr}	Import price (domestic currency)	$TINS_{i}$	Direct tax rate for institution i (i $\in$ 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 non-government institution
QD_{c}	Quantity sold domestically of domestic output	YIF_{if}	Income to domestic institution i from factor f
QE_{cr}	Quantity of exports	ΔK_{fat}^{a}	Quantity of new capital by activity a for time period t

II.2(a). CGE model equations

Production and Price Equations	
$QINT_{c\,a} = ica_{c\,a} \cdot QINTA_a$	(1)
$PINTA_a = \sum_{c \in C} PQ_c \cdot ica_{ca}$	(2)
$QVA_a = \alpha_a^{va} \cdot \left(\sum_{f \in F} \delta_{f\,a}^{va} \cdot \left(\alpha_{f\,a}^{vaf} \cdot QF_{f\,a} \right)^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}}$	(3)
$W_f \cdot \overline{WFDIST}_{fa} = PVA_a \cdot QVA_a \cdot \left(\sum_{f \in F'} \delta_{f\,a}^{va} \cdot \left(\alpha_{f\,a}^{vaf} \cdot QF_{f\,a} \right)^{-\rho_a^{va}} \right)^{-1} \cdot \delta_{f\,a}^{va} \cdot \left(\alpha_{f\,a}^{vaf} \cdot QF_{f\,a} \right)^{-\rho_a^{va}-1}$	(4)
$QF_{f\,a} = \alpha_{f\,a}^{van} \cdot \left(\sum_{f' \in F} \delta_{f\,f'\,a}^{van} \cdot QF_{f'\,a}^{-\rho_{f\,a}^{van}} \right)^{-\frac{1}{\rho_{f\,a}^{van}}}$	(5)
$W_{f'} \cdot WFDIST_{f'\,a} = W_f \cdot WFDIST_{f\,a} \cdot QF_{f\,a} \cdot \left(\sum_{f'' \in F} \delta_{f\,f''\,a}^{van} \cdot QF_{f''\,a}^{-\rho_{f\,a}^{van}} \right)^{-1} \cdot \delta_{f\,f'\,a}^{van} \cdot QF_{f'\,a}^{-\rho_{f\,a}^{van}-1}$	(6)
$QVA_a = iva_a \cdot QA_a$	(7)
$QINTA_a = inta_a \cdot QA_a$	(8)
$PA_a \cdot (1 - ta_a) \cdot QA_a = PVA_a \cdot QVA_a + PINTA_a \cdot QINTA_a$	(9)
$QXAC_{a\,c} = \theta_{a\,c} \cdot QA_a$	(10)
$PA_a = \sum_{c \in C} PXAC_{ac} \cdot \theta_{ac}$	(11)
$QX_c = \alpha_c^{ac} \cdot \left(\sum_{a \in A} \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac}} \right)^{-\frac{1}{\rho_c^{ac}-1}}$	(12)
$PXAC_{a\,c} = PX_c \cdot QX_c \left(\sum_{a \in A'} \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac}} \right)^{-1} \cdot \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac}-1}$	(13)
$PE_{cr} = pwe_{cr} \cdot EXR - \sum_{c' \in CT} PQ_c \cdot ice_{c'c}$	(14)
$QX_c = \alpha_c^t \cdot \left(\sum_r \delta_{cr}^t \cdot QE_{cr}^{\rho_c^t} + (1 - \sum_r \delta_{cr}^t) \cdot QD_c^{\rho_c^t} \right)^{\frac{1}{\rho_c^t}}$	(15)
$\frac{QE_{cr}}{QD_c} = \left(\frac{PE_{cr}}{PDS_c} \cdot \frac{1 - \sum_r \delta_{cr}^t}{\delta_c^t} \right)^{\frac{1}{\rho_c^t - 1}}$	(16)

II.2(b). CGE model equations (continued)

$QX_c = QD_c + \sum_r QE_{cr}$	(17)
$PX_c \cdot QX_c = PDS_c \cdot QD_c + \sum_r PE_{cr} \cdot QE_{cr}$	(18)
$PDD_c = PDS_c + \sum_{c' \in CT} PQ_{c'} \cdot icd_{c'c}$	(19)
$PM_{cr} = pwm_{cr} \cdot (1 + tm_{cr}) \cdot EXR + \sum_{c' \in CT} PQ_{c'} \cdot icm_{c'c}$	(20)
$QQ_c = \alpha_c^q \cdot \left(\sum_r \delta_{cr}^q \cdot QM_{cr}^{-\rho_c^q} + (1 - \sum_r \delta_{cr}^q) \cdot QD_c^{-\rho_c^q} \right)^{-\frac{1}{\rho_c^q}}$	(21)
$\frac{QM_{cr}}{QD_c} = \left(\frac{PDD_c}{PM_c} \cdot \frac{\delta_c^q}{1 - \sum_r \delta_{cr}^q} \right)^{\frac{1}{1+\rho_c^q}}$	(22)
$QQ_c = QD_c + \sum_r QM_{cr}$	(23)
$PQ_c \cdot (1 - tq_c) \cdot QQ_c = PDD_c \cdot QD_c + \sum_r PM_{cr} \cdot QM_{cr}$	(24)
$QT_c = \sum_{c' \in C'} \left(icm_{cc'} \cdot QM_{c'} + ice_{cc'} \cdot QE_{c'} + icd_{cc'} \cdot QD_{c'} \right)$	(25)
$\overline{CPI} = \sum_{c \in C} PQ_c \cdot cwts_c$	(26)
$DPI = \sum_{c \in C} PDS_c \cdot dwts_c$	(27)
Institutional Incomes and Domestic Demand Equations	
$YF_f = \sum_{a \in A} WF_f \cdot \overline{WFDIST}_{fa} \cdot QF_{fa}$	(28)
$YIF_{if} = shif_{if} \cdot \left[YF_f - trnsfr_{ro\,wf} \cdot EXR \right]$	(29)
$YI_i = \sum_{f \in F} YIF_{if} + \sum_{i' \in INSDNG'} TRII_{ii'} + trnsfr_{i\,gov} \cdot \overline{CPI} + trnsfr_{i\,row} \cdot EXR$	(30)
$TRII_{ii'} = shii_{ii'} \cdot (1 - MPS_{i'}) \cdot (1 - \overline{tins}_{i'}) \cdot YI_{i'}$	(31)
$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{ih} \right) \cdot (1 - MPS_h) \cdot (1 - \overline{tins}_h) \cdot YI_h$	(32)
$PQ_c \cdot QH_{ch} = PQ_c \cdot \gamma_{ch}^m + \beta_{ch}^m \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma_{c'h}^m \right)$	(33)
$QINV_c = IADJ \cdot \overline{qinv}_c$	(34)
$QG_c = \overline{GADJ} \cdot \overline{qg}_c$	(35)

II.2(c). CGE Model Equations (continued)

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

System Constraints and Macroeconomic Closures

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

$$QQ_c = \sum_{a \in A} QINT_{c\,a} + \sum_{h \in H} QH_{c\,h} + QG_c + QINV_c + qdst_c + QT_c \quad (38)$$

$$\sum_{a \in A} QF_{f\,a} = QFS_f \quad (39)$$

$$YG = EG + GSAV \quad (40)$$

$$\sum_{r\ c \in CMNR} pwm_{cr} \cdot QM_{cr} + \sum_{f \in F} trnsfr_{row\,f} = \sum_{r\ c \in CENR} pwe_{cr} \cdot QE_{cr} + \sum_{i \in INSD} trnsfr_{i\,row} + FSAV \quad (41)$$

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

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

Capital Accumulation and Allocation Equations

$$AWF^a_{f\,t} = \sum_a \left[\left(\frac{QF_{f\,a\,t}}{\sum_{a'} QF_{f\,a'\,t}} \right) \cdot WF_{f\,t} \cdot WFDIST_{f\,a\,t} \right] \quad (44)$$

$$\eta^a_{f\,a\,t} = \left(\frac{QF_{f\,a\,t}}{\sum_{a'} QF_{f\,a'\,t}} \right) \cdot \left(\beta^a \cdot \left(\frac{WF_{f,t} \cdot WFDIST_{f\,a\,t}}{AWF^a_{f\,t}} - 1 \right) + 1 \right) \quad (45)$$

$$\Delta K^a_{f\,a\,t} = \eta^a_{f\,a\,t} \cdot \left(\frac{\sum_c PQ_{c\,t} \cdot QINV_{c\,t}}{PK_{f\,t}} \right) \quad (46)$$

$$PK_{f\,t} = \sum_c PQ_{c\,t} \cdot \frac{QINV_{c\,t}}{\sum_{c'} QINV_{c'\,t}} \quad (47)$$

$$QF_{f\,a\,t+1} = QF_{f\,a\,t} \cdot \left(1 + \frac{\Delta K^a_{f\,a\,t}}{QF_{f\,a\,t}} - \upsilon_f \right) \quad (48)$$

$$QFS_{f\,t+1} = QFS_{f\,t} \cdot \left(1 + \frac{\sum_a \Delta K_{f\,a\,t}}{QFS_{f\,t}} - \upsilon_f \right) \quad (49)$$

11. APPENDIX III: SENSITIVITY TEST OF THE MODEL

As we discussed in Chapter Two of the report, elasticities in the trade functions (both imports and exports) to capture the imperfect substitution between goods produced for domestic market and for export and between goods consumed and produced domestically and imported are drawn from literature. The sensitivity test, hence, focuses on whether model results are sensitive to the choice of such substitution elasticities. We do it by increasing and decreasing the level of substitution elasticities applied in the DCGE model by 25 percent uniformly for all commodities on both export and import sides. We focus on the discussion of prices, output, economic growth and poverty rate for the test results. The scenario chose for the discussion is Scenario 21 in which agriculture and nonagriculture grow side by side. Table III.1 reports the test result of prices for selected agricultural products. We report the levels of prices (normalized by the prices in the first year of the model) by 2015 under Scenario 21 with different levels of elasticities applied in the trade functions, i.e., either 25 percent higher or 25 percent lower than the elasticities used in the model. The differences (in percentage) from the prices for same commodities under the same scenario (Scenario 21) as the model results of the report are also reported. As shown in the table, the model results, in terms of commodity prices (which are endogenous variables in the model), are not sensitive to the choice of elasticities in the range of -25% – +25% of those applied in the model. For most prices, the differences are less than 1% (positive or negative) and the biggest difference is -3.24 percent in the case of rice when substitution elasticitites in trade functions reduce by 25 percent.

Table III.1. Sensitivity test: Price comparison

	With substitution elasticity 25% higher		Model results in the report	With substitution elasticity 25% lower	
	Level of price by 2015	% difference from the model result		Level of price by 2015	% difference from the model result
Maize	1.04	-1.27	1.05	1.07	1.91
Rice	0.77	2.27	0.75	0.73	-3.24
Potatoes	1.32	-0.22	1.32	1.33	0.26
Vegetables	0.82	-0.22	0.82	0.82	0.27
Beef	0.75	-0.25	0.75	0.75	0.30
Poultry	0.58	-0.22	0.58	0.58	0.27

Notes: 1. Substitution elasticities are those used in Armington (for imports) and CET (for exports) functions

2. Level of price is normalized to 1 in the first year Table III.2 reports the sensitivity test results for production output and the table is designed in a similar way as table III.1. Again, with substitution elasticities increase or decrease by 25 percent, the differences in the output of model result for most commodities are less than 1%. The maximum difference is -4.0 percent when elasticities decrease by 25 percent.

Table III.2 Sensitivity test: Production comparison

	With elasticity 25% higher		Model results in the report	With elasticity 25% lower	
	Level of production by 2015	% difference from the model result		Level of production by 2015	% difference from the model result
Wheat	46	0.6	45	45	-0.6
Maize	161	0.0	161	162	0.8
Rice	239	1.0	237	234	-1.4
Sorghum	264	0.0	264	264	0.0
Potatoes	2,107	0.0	2,108	2,110	0.1
Sweet potatoes	949	0.0	949	949	0.0
Cassava	1,060	0.0	1,060	1,060	0.0
Other roots	209	0.0	209	209	0.0
Pulses	432	0.0	432	432	0.0
Vegetables	912	0.0	912	912	0.0
Bananas	4,610	0.0	4,609	4,608	0.0
Fruits	598	0.0	598	598	0.0
Oil crops	66	-0.1	66	67	0.1
Coffee	74	0.0	74	73	-0.7
Tea	56	0.4	56	55	-0.4
Other exports	439	3.1	426	409	-4.0
Bovine cattle	28	-0.1	28	28	0.1
Sheep/ goats	4	-0.1	4	4	0.1
Swine	3	-0.1	3	3	0.2
Poultry	4	-0.1	4	4	0.1
Raw milk	34	0.1	34	34	-0.1
Eggs	6	0.0	6	6	0.0
Other livestock	4	0.5	4	4	-0.6
Forestry	82	0.0	82	83	0.1
Fishing	12	0.1	11	11	-0.2

Notes: 1. Substitution elasticities are those used in Armington (for imports) and CET (for exports) functions
2. Level of crop production is in 1000 metric ton and level of livestock production is sectoral value-added in billion Rwf.

Tables III.3 and III.4 report sensitivity test results of annual growth rate for GDP and aggregated sectoral GDP and poverty rates by 2015. Similar small differences are seen in both tables with 25 percent of increases or decreases in the substitution elasticities. Results summarized in the four tables let us feel confidence for the robustness of the model results as the key endogenous variables are not sensitive to the choice of substitution elasticities in the trade function.

Table III.3 Sensitivity test: Growth rate comparison

	With elasticity 25% higher		Model results in the report	With elasticity 25% low	
	Annual growth rate	% difference from the model result		Annual growth rate	% difference from the model result

GDP	6.9	0.1	6.9	6.9	-0.1
AgGDP	6.5	0.1	6.5	6.5	-0.1
Cereals	8.0	0.4	7.9	7.9	-0.6
Roots	4.1	0.0	4.1	4.1	0.0
O. staples	5.6	0.0	5.6	5.6	-0.1
Export crops	8.7	0.2	8.6	8.6	-0.3
Livestock	12.3	0.0	12.3	12.3	0.0
Other agr.	8.6	0.0	8.6	8.6	0.0
Industry	7.4	-0.3	7.5	7.5	0.4
Food processing	10.1	-0.4	10.2	10.2	0.5
Services	7.2	0.3	7.2	7.2	-0.3
Trade	8.3	0.4	8.3	8.3	-0.4
Transport	8.5	0.1	8.5	8.5	-0.1

Note: Substitution elasticities are those used in Armington (for imports) and CET (for exports) functions

Table III.4 Sensitivity test: Poverty rate comparison

	With elasticity 25% higher		Model results in the report	With elasticity 25% lower	
	Poverty rate by 2015	% difference from the model result		Poverty rate by 2015	% difference from the model result
National	36.86	-0.1	36.90	36.98	0.2
Urban	18.52	0.6	18.41	18.41	0.0
Rural	40.52	-0.2	40.59	40.69	0.2

Note: Substitution elasticities are those used in Armington (for imports) and CET (for exports) functions