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Exploring Growth Linkages and Market Opportunities for Agriculture in Southern Africa

Alejandro Nin Pratt
International Food Policy Research Institute

Xinshen Diao
International Food Policy Research Institute

Abstract

The heterogeneity of southern African countries offers the region a unique opportunity to exploit agricultural potential and trade opportunities through regional integration. We analyze the implications of such opportunities using a regional general equilibrium model. We find that growth in South Africa benefits the region's low-income countries through increased demand for their agricultural exports, higher prices that stimulate production for domestic markets, and slower decline of prices from increased production. Agricultural productivity growth, however, is necessary for low-income countries to take advantage of South Africa's growth. The largest benefits for low-income countries result from rising productivity of grain and livestock production.

- **JEL classification:** C68, D58, F11, F15, O33, O55, Q17, Q18
- **Keywords:** Agriculture, Applied General Equilibrium, Growth Linkages, Productivity, Regional Integration, Southern Africa, Trade

*Corresponding address: Alejandro Nin Pratt, Development Strategy and Governance Division, International Food Policy Research Institute, 2033 K Street, NW. Washington D.C., 20006. U.S.A. Tel: +202 862 5689; Fax: +202 467 4439, E-mail: a.ninpratt@cgiar.org
Xinshen Diao, Development Strategy and Governance Division, International Food Policy Research Institute, 2033 K Street, NW. Washington D.C., 20006. U.S.A. Tel: +202 862 8113; Fax: +202 467 4439, E-mail: x.diao@cgiar.org

I. Introduction

Strengthening regional economic linkages that offer mutual benefits across countries is an important part of development strategies leading to economic growth and poverty reduction in Sub-Saharan Africa. Regionalism, in fact, has received increasing attention as a result of growing fears in Africa and in the international community of African marginalization in the global economy. As a result, several regional initiatives have been developed across the continent. In the case of southern Africa, there is a remarkable degree of consensus that regionalism is not only desirable but necessary (Gibb, 2001). For this reason, the creation of regional institutional frameworks and programs has been central to cooperation efforts in southern Africa and resulted in regional schemes such as the Common Market for Eastern and Southern Africa (COMESA), the Southern Africa Development Community (SADC), and the Southern Africa Custom Union (SACU).

A distinctive characteristic of southern Africa is the dominant presence of South Africa, a presence that goes beyond a mere geographic sense. South Africa has been part of a regional economy characterized by profound economic and political ties that go back to colonial times, linking most of the neighboring states and with a significant degree of economic integration. According to Nyirabu (2004) "…South Africa's involvement in the regional economy whether as a recipient of migrant labor from countries as far as Tanzania, as a provider of transport services, or as en exporter of manufactured goods has historically been of sizeable significance both to South Africa and to most of it neighboring countries." The size of South Africa's economy and the economic and political linkages between countries in the region are among the main arguments supporting the view that joint development of regional resources and infrastructure can make a great potential contribution to economic growth and development both in South Africa and the rest of SADC.

However, critics of regional integration in southern Africa have raised voices against this process fearing that integration will be built upon South Africa, as the region's single dominant economy. These critics assert that potential economic benefits of regionalism in southern Africa are often exaggerated and contend that the lack of complementarity between integrating states is one of the principal reasons behind the limited potential for regionalism (see Gibb (2001), and Radelet, (1997)). These conflicting views of the possible impact of regional integration in southern Africa rise questions about the actual opportunities and challenges that

low-income countries face in the process of integrating to a middle-income, bigger and more diversified economy. How important are growth linkages between South Africa and other countries in the region? Are there complementarities that low-income countries can exploit? Which sectors, if any, offer low-income countries the best possibilities to expand production, diversify exports and accelerate GDP growth in the context of regional integration?

This study attempts to answer these questions using a computable general equilibrium model (CGE). The focus is on the economic linkages between middle- and low-income countries in southern Africa and the implications of such linkages for economic growth. Based on southern Africa's specific characteristics and linkages, we argue that agriculture could play a major role in the process of regional integration. First, as South Africa accelerates growth based on the expansion of mineral products, manufactures and services, with agriculture lagging behind as happened in recent years, the region will face a growing excess demand for agricultural products. Second, there is an unexploited agricultural growth potential in low-income countries. With adequate policies and investments, low-income countries can reduce the gap between actual and potential agricultural productivity and take advantage of the growing regional demand for agricultural products. Finally, another possibility for creating regional growth opportunities is the as-yet unexploited potential in agricultural trade. Protection, high transaction costs and underdeveloped production structures—reflected in low productivity levels and inadequate infrastructure— are significant obstacles for regional trade. A growing demand for agricultural products, together with, policy coordination, sectoral cooperation and investments to increase agricultural productivity could result in a significant impact on the economies of low-income countries.

The regional CGE model developed for this study is used to simulate growth in non-agricultural production in South Africa, productivity growth in different agricultural subsectors in low-income countries, and simultaneous agricultural and non-agricultural growth in low- and middle-income countries respectively. Results of the CGE simulations show that growth in middle-income countries benefits low-income countries through increased demand for their agricultural exports and higher prices that stimulate agricultural production for domestic markets. Agricultural productivity growth, however, is necessary for low-income countries to take advantage of middle income countries' growth. Comparing the impact of productivity growth in different agriculture sub-sectors, we find that grain and livestock production generates more growth in gross domestic product (GDP) and

food consumption than non-traditional export crops. Unlike other regions where growth in grain production is likely to be constrained by limited domestic demand, growing middle-income economies in southern Africa provide additional demand for grains and livestock, slowing the decline of grain prices that result from increased production in low-income countries.

The rest of this paper is organized as follows: section II further discusses the main characteristics that offer southern Africa special opportunities to foster development and agricultural growth through regional linkages. Section III presents the CGE model used in this study and the definition of the simulation scenarios, while section IV presents simulation results looking at the potential contribution of different sub-sectors to growth. Section V provides recommendations and conclusions.

II. Regional Agricultural Growth Opportunities

Southern Africa's economic structure allows us to identify several characteristics that offer special opportunities to foster development and agricultural growth through regional linkages. Here we highlight three of these characteristics: A) Complementarities between low- and middle-income economies; B) unexploited agricultural growth potential; and C) unexploited agricultural trade opportunities. In what follows we discuss the implications of these characteristics for regional integration.

A. Complementarities between low- and middle-income countries

Southern Africa is the only region in the African continent with a number of middle- and low-income countries in close proximity to each other. Potential complementarity between these economies could favor regional production and trade, benefiting agriculture and the poor in low-income countries. While agriculture accounts for only 3 percent of total GDP of the region's middle-income countries as a group, it plays a significant role in low-income countries where it contributes with 20 percent of GDP and a significant share of GDP growth. Agriculture is also the main source of employment in low-income countries, where the rural population represents 68 percent of total population and concentrates the majority of the poor (Tables 1 and 2).

South Africa is already the region's engine of growth, with per capita income of $3,002 per year, 38 percent of the region's total population, and more than 70

Table 1. Income and Poverty for Southern African Countries

Country	GDP per capita[c] US$	Rural population[c] (%)	Poverty head count[a] (%)	Year	AgGDP[c] (%)
Middle-income countries[b]	2,520	48.1	24.9	-	3.4
Mauritius	4,073	58.1	10.2	1992	6.4
Botswana	3,372	50.1	30.7	1993	2.5
South Africa	3,002	41.6	10.7	2000	2.8
Namibia	1,805	68.1	34.9	1993	8.7
Swaziland	1,350	72.9	40.0	1995	9.5
Angola	803	64.5	72.0		6.4
Low-income countries[b]	310	67.9	47.8	-	19.9
Lesotho	518	70.5	36.4	1995	15.1
Zimbabwe	479	63.3	56.1	1995	15.4
Zambia	342	59.9	63.5	1998	17.6
Mozambique	243	65.6	37.9	1996	24.0
Malawi	154	84.5	41.6	1997	33.6
Southern Africa	1,510	57.1	35.4	-	4.9
Sub-Saharan Africa	509	64.0	51.0	-	17.5
Sub-Saharan Africa, not including Southern Africa	297	65.9	54.5	-	31.0

[a] Poverty headcount ratio at $1 a day (PPP) (% of population). Poverty head count for Swaziland is from FAOSTAT, Food Security Statistics.
[b]Weighted averages. Low-income countries are Lesotho, Malawi, Mozambique, Zambia, and Zimbabwe. Middle-income countries are Angola, Botswana, Mauritius, Namibia, South Africa, and Swaziland.
[c]Year 2002
Source: World Bank World Development Indicators, 2005.

percent of its GDP. South Africa could influence growth in other countries through different channels: international trade, spillover effects, FDI, and financial linkages. This country could also affect business and consumer confidence in other African countries, given the size of its economy and its leadership role in regional economic and political initiatives. Arora and Vamvakides (2005) econometrically estimate this effect using data for the period 1960–1999. Their results indicate that an increase of 1 percentage point in South African economic growth is correlated with a 0.5–0.75 percentage point increase in growth in the rest of southern Africa.

The resurgence of the South African economy after the end of the Apartheid in the early 1990s has allowed the country to significantly increase its foreign trade, including trade with its SADC neighbors (Thurlow 2004). Further liberalization of capital markets during the late 1990s also caused huge capital outflows from South Africa into the SADC region and the rest of Africa: according to Rumney and

Table 2. Growth Decomposition by Sector in the Low Income Southern African Countries (Average 1985-2002)

	Share in GDP in 1985 (%)			Growth rate (%)				Contribution to GDP growth (%)		
Country	Agriculture	Industry	Services	Agriculture	Industry	Services	GDP	Agriculture	Industry	Services
Low-income countries[a]	31.1	25.8	43.2	2.7	1.8	2.7	2.4	34.2	18.5	47.2
Coastal										
Mozambique	47.5	13.2	39.3	5.3	8.12	5.1	5.7	44.8	19.2	36.0
Land-locked										
Lesotho	22.7	27.2	50.0	1.8	5.9	3.7	3.9	10.8	41.7	47.5
Malawi	42.9	21.9	35.2	3.6	1.1	2.1	2.4	61.3	9.1	29.5
Zimbabwe	22.7	28.0	49.3	1.0	-0.2	2.3	1.0	17.0	-3.8	86.8
Mineral-based										
Zambia	14.6	46.8	38.6	2.2	0.0	1.9	1.3	30.6	-1.8	71.2

a/ Weighted averages. Low-income countries are Lesotho, Malawi, Mozambique, Zambia, and Zimbabwe.
Source: World Bank. World Development Indicators, 2005

Pingo(2004), South Africa accounts for 25 percent of total FDI flowing into the SADC region. Many of these investments have been in agriculture or agriculture-related sectors. For example, South African supermarkets have created demand for high-value, locally produced products and have established supply chains both within and outside the region (see also Weatherspoon and Reardon, 2003). There have also been South African investments in roads, ports, and other market-related infrastructure in neighboring countries, which also improve market conditions for both agricultural and nonagricultural exports in the region as a whole.

Angola is another country that has potential to generate regional growth dynamics in southern Africa. Since its postwar economic recovery began some 10 years ago, Angola has averaged almost 7 percent in annual GDP growth. As a country rich in natural resources and with annual per capita income of $803, Angola depends on imports for most agricultural products. For example, almost 60 percent of the country's cereal demand has to be met by imports.

B. Unexploited agricultural growth potential

Regional growth opportunities also come from the region's agricultural potential. This potential draws on a classificatory scheme developed by Dixon et al. (2001), which includes measures such as agro-ecological conditions and population densities. According to this classification, all five low-income southern African countries have high agricultural potential. However, the poor performance of the agricultural sector, mainly a result of bad policies or politically unstable environments, has constrained the region from exploiting this potential. For example, an urban bias in economic development policies that largely emphasizes the mineral sector has significantly hurt Zambia's agricultural growth (Thurlow and Wobst 2004). In Zimbabwe, recent political instability has resulted in declining agricultural production. While five-year average yields for maize production in Zambia and Zimbabwe were only 30–40 percent below South Africa's level during the early 1980s, the yield gap has increased to 50 percent in Zambia and 80 percent in Zimbabwe in recent years (2003–2005) (Table 3). These and other failures to exploit the region's agricultural potential have been largely responsible for the transformation of southern Africa into a food-deficit region.

Stagnant productivity growth in agriculture is the main factor that caused the region to become dependent on food imports, restraining production and growth in major agricultural sub-sectors like cereals and livestock. At the same time, strong population growth throughout the region and increased per capita income in some

Table 3. Land Productivity in Low-Income Southern Africa Compared to Land Productivity in South Africa (In Kilograms/Hectare)

	1979-81 average					2003-05 average				
	Malawi	Mozambique	Zambia	Zimbabwe	South Africa	Malawi	Mozambique	Zambia	Zimbabwe	South Africa
Maize	1,185	572	1,805	1,615	2,530	1,179	1,057	1,539	598	3,119
Wheat	1,152	1,150	3,488	4,782	1,101	675	1,088	6,429	3,925	2,211
Rice	1,153	811	510	588	2,308	1,306	1,079	1,190	2,400	2,286
Roots & tubers	6,397	4,157	6,630	3,823	12,002	14,457	5,965	5,747	4,876	27,537
Pulses	603	381	340	566	901	512	477	531	771	1,187
Oilcrops	197	167	164	193	347	202	151	120	123	473
Fruits	4,375	5,596	5,656	4,693	13,101	9,456	5,730	6,357	5,579	17,509
Vegetables	7,348	6,117	7,401	6,239	17,600	9,773	5,497	6,982	6,879	19,427
Cotton	872	406	526	1,538	1,373	871	435	1,127	681	2,021
Sugarcane	113,858	40,121	93,608	103,775	75,463	105,000	13,333	105,882	90,301	63,885
Tobacco	772	1,123	1,034	1,884	1,005	548	1,412	1,067	1,719	2,492

Source: Calculated from FAOSTAT (FAO, 2006)

of the middle-income countries, increased food demand for cereals and livestock. The result has been a sharp increase of imports of major agricultural products. Although the region allocates 50 percent of agricultural land to cereal production, southern Africa as a whole has become a grain-deficit region in recent years (FAO, 2006). Cereal imports increased from 12 percent of cereal demand in 1977–1981 to 22 percent in 1998–2002, with a gap between demand and production of 20 percent in low-income countries. Moreover, all southern African countries with the only exception of South Africa are currently maize-deficit countries even though the land area allocated to maize in 2002 increased by more than 30 percent with respect to the area in 1980 in the low-income country group.

Similarly, demand for livestock products has grown more rapidly than supply (2.6 and 1.9 percent per year respectively during 1998-2002). Thus, the region has shifted from a meat surplus in the early 1980s to a deficit in recent years. In low-income countries, 14 percent of the milk and 6 percent of the poultry meat consumed is imported every year. For the region as a whole, 11 percent of the meat and 17 percent of the milk consumed is imported (1998–2002 average). A recovery of maize productivity to its historical highest level could significantly improve low-income countries' competitiveness and result in import substitution of maize, livestock, and other commodities, providing these countries with more growth opportunities in agriculture.

C. Unexploited agricultural trade opportunities

Regional growth opportunities could result from unexploited trade potential. As mentioned earlier, regional schemes to foster cooperation among southern African countries, such as COMESA, SADC, and SACU, have placed great importance on integration in the region's development strategy. In this context, removal of tariffs and non-tariff barriers is an important issue in the region because they affect trade between middle- and low-income countries that do not belong to SACU (such as Malawi, Mozambique, Zambia, and Zimbabwe). South Africa imposes high tariffs on imports of dairy products, cereals, and textiles—sectors with potential for low-income countries in the region to increase exports. On the other hand, the low-income countries impose high tariffs on textiles, fruits, vegetables, and processed food products—sectors with potential for intraregional trade. Zambia is an exception, with lower tariffs on these products than other low-income countries in the region. The elimination of agricultural tariffs among SADC countries would benefit the region in terms of real agricultural GDP, national income, and

agricultural output (see, for example, Diao and Robinson 2003; Karingi et al., 2002).

However, tariffs are not the only obstacle to increased regional trade and the analysis of integration in southern Africa goes beyond trade liberalization. To explain low trade in the region, several studies have stressed the importance of transport and transaction costs, inadequate infrastructure, the lack of diversification in comparative advantages, and underdeveloped production structures (see, for example, Chauvin and Gaulier, 2002; Cassim, 2000; Davies, 1996; Geda and Kibret, 2002; Goldstein, 2004; Holden, 1996; Jenkins et al., 2000; Longo and Sekkat, 2001; Nyirabu, 2004; Radelet, 1997). The importance of these factors and the difficulties that low-income countries find to compete and diversify their exports are reflected in their participation in regional markets (Table 4). During 1990-1999, intra-southern African exports grew by 13 percent annually, resulting in increased importance of regional markets for southern African countries (rising from 7 percent in 1990 to 11 percent in 1999). About 75 percent of regional export expansion is explained by increased exports from South Africa, while Mozambique, Zimbabwe, Zambia, and Angola explain almost 80 percent of the increase in imports. As a consequence, South Africa shifted its position from a net importer from the region (US$58 millions) in the early 1990s, to a net exporter (US$317 millions) by the end of the decade, while all other countries saw large increases in their imports from South Africa.

One of the challenges faced by low-income countries in the process of regional integration is to overcome the problems of high transaction costs and underdeveloped production structures that limit their possibilities to compete in the region. Under the present circumstances, regional integration could exacerbate the tendency

Table 4. Intraregional Agricultural Trade in Southern Africa (US$ million)

	Exports			Imports		
Country	1990	1999	Increase	1990	1999	Increase
Angola	0.1	0.1	0.0	9.9	87.7	77.8
Malawi	34.7	24.0	-10.7	31.5	79.5	48.1
Mauritius	1.4	1.8	0.3	33.6	77.8	44.3
Mozambique	0.1	27.6	27.5	41.5	176.3	134.9
South Africa[a]	67.9	493.2	425.3	125.7	176.2	50.5
Zambia	3.1	46.1	43.1	8.1	75.2	67.2
Zimbabwe	165.4	243.6	78.2	22.5	163.6	141.1
Total	272.8	836.5	563.7	272.8	836.5	563.7

a/ Only aggregated data of trade for SACU was available. SACU trade in the region is mainly explained by South Africa

Source: Authors' calculations using UN-COMTRADE database: http://comtrade.un.org/, 2005

towards economic polarization (Davies, 2001). Rather than trade integration alone, the region needs a program that combines trade integration, sectoral cooperation, and policy coordination to address the major challenges faced by low-income countries (Davies, 2001; Ramsamy, 2001).

In sum, we have presented a number of distinctive characteristics of southern Africa's economy that together offer a unique opportunity to foster the region's economic development and agricultural growth through regional linkages. In what follows we analyze the economic growth linkages between middle- and low-income countries in southern Africa. In particular, we are interested in how these linkages are affected when we loosen the agricultural productivity constraint in low-income countries.

III. A Regional General Equilibrium Model for Southern Africa

A. The model and data description

To evaluate fully the importance of economic linkages between southern African countries and their role in economic growth, it is necessary to have an economy-wide view. Therefore, we present in this section a regional general equilibrium model (CGE) that is used to assess how economic linkages in the region affect strategic options and priorities for agricultural development in southern Africa. A regional CGE model is specially suited for this kind of analysis for its ability to trace the consequences of changes in a particular sector of a particular country throughout the entire regional economy (see Hertel, 1999 for a discussion of the use of CGE models in the analysis of agriculture and resource policy)[1].

The computable general equilibrium (CGE) model, as its name suggests, consists of an economy-wide, multi-sectoral model that solves simultaneously and endogenously for both quantities and prices. Production technology in the model is represented by fixed input-output coefficients for intermediate goods and constant elasticity of substitution (CES) function for the following primary inputs: two types of labor (skilled and unskilled), land, other natural resources, and capital. While supply of other production factors is assumed to be fixed within each country, the model assumes the existence of unemployment in unskilled labor among low-

[1]Input-output models can also be used for this kind of analysis but CGE models allow a more flexible treatment of the consumer side of the economy and they are less rigid in the requirements placed on the productive side (see Scarf and Shoven, 1984).

income southern African countries. Production technology varies across sectors and countries and is calibrated to the countries' data.

Our regional CGE model solves consumer demand by maximizing a Stone-Geary utility function, which implies linear expenditure systems (LES) for individual commodities. The income elasticities used to derive the marginal budget shares for consumption are from Reimer and Hertel (2004); for example, income elasticities for grains range from 0.4 to 0.5 for the low-income African countries. The subsistence parameters in the demand functions are calculated by assuming a Frisch parameter (together with income elasticities) for each individual country. Once we know the income elasticities and subsistence parameters, price elasticities (including own and cross price ones) can be derived by imposing the homogeneity condition on the LES functions. This procedure results in price elasticities of demand for grains, for example, of between -0.15 and -0.34. Income levels, consumption patterns, and marginal propensity to consume, also vary across countries. The incomes of consumers are determined in the factor markets after subtracting taxes. The demand for commodities by sector is determined from these incomes (given household savings propensities) and from the government consumption functions.

The model assumes price-sensitive substitution (imperfect substitution) among foreign goods and domestic production and among goods produced by different trading partners. This is a commonly used and necessary assumption for a multi-region CGE model where two-way trade in the data is observed. Because of this assumption, domestic goods cannot fully substitute for imports, even if productivity improves in the domestic production sector. CGE results have been shown to be sensitive to these trade elasticities. In particular, in scenarios where we simulate growth of non-agricultural sectors in middle income countries, the use of small trade elasticities could result in large terms of trade effects that favor agriculture in low income countries, driving the results of our model simulations. We try to minimize these effects on the simulation results by employing a group of substitution elasticities with much higher value than those econometrically estimated and used in the literature (see, for example, McDaniel and Balistreri 2003; Gallaway et al., 2003; Zhang and Verikios 2003; and Hertel et al. 2003).

The model was calibrated using the Global Trade Analysis Project (GTAP) database (Dimaranan, 2006). The aggregation we use includes six individual southern African countries: Botswana, Malawi, Mozambique, South Africa, Zambia, and Zimbabwe, and two aggregated sub-regions: the rest of SACU and the rest of southern Africa. Our focus is the low-income countries in southern Africa, which

are explicitly defined in the GTAP database used in the study: Malawi, Mozambique, Zambia, and Zimbabwe. In the original database, Lesotho is aggregated into the "rest of SACU." Also included are three countries in East Africa: Madagascar, Tanzania, and Uganda, a "rest of Sub-Saharan Africa" region, two North African countries (Morocco and Tunisia) and a "rest of North Africa" region. Outside Africa, the model includes Africa's two major trading partners (the United States and the European Union), other European countries as a group, as well as China, India and a "rest of Asia" region. Finally, the "rest of the world" is a separate region, aggregating all other countries.

As the focus is on agriculture, the model includes 23 agricultural and agriculture-related sectors and 11 non-agricultural sectors, many of which, such as transportation and textiles, directly link to the agricultural sector. Inclusion of more disaggregated agricultural sub-sectors is constrained by the GTAP database, which aggregates many regionally important agricultural commodities (such as tobacco for export or cassava and other root and tuber crops to meet domestic demand) in a sector called "other crops". For the purposes of this study, we split this sector into two: "export other crops" and "domestically consumed other crops". We use "export other crops" to represent traditional export tree crops and tobacco, while the "domestically consumed other crop" sector represents roots and tubers used as staples. Similarly, we split the GTAP's aggregated vegetable and fruits sector in two: "non-traditional exportables" and "fruits and vegetables for domestic markets".

Two transport sectors in the GTAP database, "water transport" and "other transport," provide data on transport costs incurred by other sectors in the production process and also affect price margins for international trade. International transportation margins for African countries are calculated using bilateral data on c.i.f. and f.o.b. prices based on information from Limao and Venables (2002). While the market value of such price gaps is treated as exports of transportation services from exporting countries to importing countries, the margins will be endogenously affected by the changes in the producer price for the domestic transportation sector. Improving the transportation sector's productivity lowers the unit cost of services provided by the sector, which causes exports to become more profitable and imports to become cheaper at given prices, as the gap between c.i.f. and f.o.b. prices becomes smaller. Due to data limitations, we did not consider price margins in domestic markets.

Table 5. CGE Model Simulation Scenarios

Scenario	South Africa	Botswana	Rest of SACU[a]	Rest of SADC[b]	Malawi	Mozambique	Zambia	Zimbabwe
				% growth rate in sector's TFP				
Scenario 1: Growth in South Africa Non-agriculture								
Non-agriculture	5.8	-	-	-	-	-	-	-
Scenario 2: Growth in maize & livestock in low-income countries								
Maize & other coarse grains	-	-	-	-	4.5	4.5	4.5	-
Bovine Meat	-	-	-	-	4.5	4.5	4.5	-
Pig meat and poultry	-	-	-	-	4.5	4.5	4.5	-
Milk	-	-	-	-	4.5	4.5	4.5	-
Scenario 3: Growth in non-traditional exports in low-income countries								
Fruits & vegetables	-	-	-	-	4.5	4.5	4.5	-
Oilseeds	-	-	-	-	4.5	4.5	4.5	-
Cotton	-	-	-	-	4.5	4.5	4.5	-
Scenario 4: Combination of an expansion of Scenario 1 with Scenario 2								
Non-agriculture	5.8	7.3	6.3	8.3	-	-	-	-
Maize & other coarse grains	-	-	-	-	4.5	4.5	4.5	
Bovine meat	-	-	-	-	4.5	4.5	4.5	
Pig meat and poultry	-	-	-	-	4.5	4.5	4.5	
Milk	-	-	-	-	4.5	4.5	4.5	
Scenario 5: Combination of an expansion of Scenario 1 with Scenario 3								
Non-agriculture	5.8	7.3	6.3	8.3	-	-	-	-
Fruits & vegetables	-	-	-	-	4.5	4.5	4.5	-
Oilseeds	-	-	-	-	4.5	4.5	4.5	-
Cotton	-	-	-	-	4.5	4.5	4.5	-

a/ Lesotho, Namibia, and Swaziland.

b/ Angola, Democratic Republic of Congo, Madagascar and Mauritius

B. Simulation scenarios

The study includes three groups of growth scenarios (Table 5), modeling growth as an exogenous increase in total factor productivity (TFP) of selected sectors. The first group (Scenario 1) focuses on the role of South Africa as a possible engine of growth for the low-income southern African countries. The purpose of this scenario is to quantify the linkages between South Africa and low-income countries by measuring the impact of South Africa's growth on growth in low-income countries. The second group of scenarios analyzes the low-income countries' own growth engines, where agricultural TFP in low-income countries is increased to reduce the productivity gap between low and middle income countries. We consider two types of agriculture-based growth: TFP growth in maize and livestock (Scenario 2) examines the role of domestic and regional food markets, while TFP growth in fruits and vegetables, oilseeds, and cotton (Scenario 3) evaluates the role of non-traditional exports in regional growth. The third group of scenarios (Scenarios 4 and 5), focuses on growth linkages between middle- and low-income southern African countries. Scenario 4 combines TFP growth in the nonagricultural sectors of South Africa and other middle-income countries with growth in the maize and livestock sectors of low-income countries. Scenario 5 analyses growth in non-traditional agricultural export sectors, combining low-income countries' productivity growth in fruits and vegetables, oilseeds, and cotton with non-agricultural growth in middle-income countries.

IV. Alternative Growth Scenarios for Southern Africa's Agriculture

A. Agriculture in low-income countries benefits from growth in south africa

Scenario 1 models the impact of economic growth in South Africa on the low-income southern African countries. Thus, this first scenario considers the opportunities for low-income Southern African countries arising from the widening excess demand for agriculture and food products currently observed in South Africa. In this simulation, South Africa's GDP is targeted to grow by 4.5 percent annually, with such growth primarily driven by exogenous TFP growth in both the manufacturing and services sectors. This growth rate reflects the trend of the economy in recent years and is consistent with the target set by South Africa's government for the next five years in the Accelerated and Shared Growth Initiative for South

Africa (see South African Government Information, 2006 and Statistics South Africa, 2006). There is no additional exogenous productivity growth in the agricultural sector in South Africa, nor in any other country in the region or outside the region. Thus, observed growth in South Africa's agriculture or in the other southern African countries is solely endogenously induced by the non-agricultural sector's growth in South Africa.

We first use growth elasticities to measure the impact of South Africa's growth on the neighboring economies. Relatively large growth elasticities are observed in the region's other SACU countries (as a group): a 1 percent growth in South Africa stimulates 0.33 percent of total GDP growth in other SACU countries. Growth elasticities for the four low-income southern African countries are relatively small, but still significant: Malawi, 0.15; Mozambique, 0.16; Zambia, 0.20; and Zimbabwe, 0.10. It is important to keep in mind that our analysis may significantly underestimate the potential growth linkages in the region because of the static nature of the model, which does not allow us to capture capital investment effect and spillovers from technology embodied in both investment and imports of capital goods.

The aggregate effect of South Africa's growth in the region is presented in Table 6, together with the aggregate effect of the other four scenarios. We focus here on the results for Scenario 1. Results for Zimbabwe are not included, given the particular evolution of its economy and the difficulty of deriving lessons from the present situation.[2] Growth in South Africa generates additional annual growth in real GDP in Malawi and Mozambique of 0.7 percent and almost 1 percent in Zambia. Increased agricultural production, together with higher agricultural prices, has a profound effect on real agricultural income, which increases by 0.67–1.23 percent annually in the three low-income countries, as a result of growth in South Africa's GDP of 4.5 percent a year. While raising food prices may hurt the urban poor, total food consumption in the region increases by 1.9 percent per year, with growth in the low-income countries ranging from 0.9 percent per year in Mozambique to 1.2 percent per year in Zambia.

How is growth in South Africa's manufacture and services linked to growth in real agricultural income in low-income countries? Non-agricultural productivity growth increases income in South Africa, resulting in increased demand for both

[2]Zimbabwe is facing its worst economic crisis since its independence in 1980, with record inflation of nearly 1,000 percent, the highest in the world. The country also faces acute shortages of food, gasoline and imports.

Table 6. Aggregate Effect of CGE Model simulations

Scenario	Real GDP	Real AgGDP	Agricultural trade		Food price index	Food consumption
			Exports	Imports		
	Additional annual growth rate (%)					
Scenario 1						
Region	3.30	1.03	-0.02	1.11	0.45	1.88
Malawi	0.65	0.88	0.45	0.33	0.34	1.00
Mozambique	0.70	0.67	-0.48	0.70	0.41	0.87
Zambia	0.90	1.23	1.19	0.64	0.28	1.21
Scenario 2						
Region	0.02	0.29	0.00	-0.05	-0.04	0.29
Malawi	0.48	2.44	-0.19	-2.71	-1.33	2.59
Mozambique	0.34	1.80	1.09	-0.79	-0.76	1.58
Zambia	0.24	1.68	0.98	-1.90	-0.91	2.03
Scenario 3						
Region	0.01	0.09	0.05	0.01	0.00	0.04
Malawi	0.19	0.78	0.09	-0.36	-0.09	0.28
Mozambique	0.17	0.54	2.67	0.15	0.02	0.25
Zambia	0.18	0.65	2.29	-0.67	-0.07	0.28
Scenario 4						
Region	4.58	2.50	0.10	2.02	0.57	3.27
Malawi	1.16	3.42	0.21	-2.85	-0.99	3.63
Mozambique	1.06	2.51	0.51	-0.23	-0.34	2.46
Zambia	1.20	2.96	1.90	-1.43	-0.62	3.32
Scenario 5						
Region	4.57	2.30	0.14	2.07	0.60	3.02
Malawi	0.88	1.78	0.48	-0.54	0.26	1.31
Mozambique	0.89	1.26	2.10	0.70	0.45	1.12
Zambia	1.14	1.93	3.24	-0.21	0.23	1.56

Source: CGE model results.

agriculture and non-agriculture products. As factors of production re-allocate from agriculture to growing manufacture and services sectors, agricultural supply in South Africa cannot keep pace with demand growth. As a result, prices of agricultural commodities increase, deteriorating South Africa's competitiveness. Through price transmission (even if imperfect), increased border prices in South Africa induce price increases in the domestic markets of the other southern African countries, stimulating production of exportable and non-exportable agricultural

[3]An increase in regional agricultural prices could also be related to the model assumption of imperfect substitution between domestically produced and imported/exported goods in each country. See discussion of trade elasticities in section III.A.

Table 7. Effects on Agricultural Sub-Sectors of CGE Model Simulations

Scenario/country	Cereals	Livestock	Crops for domestic market [a]	Non-traditional exports[b]	Traditional exports[c]	Total
Share in agriculture value-added (%)						
Malawi	24.3	3.7	58.9	5.0	8.1	100
Mozambique	12.6	5.3	76.0	1.9	4.3	100
Zambia	29.9	13.6	25.3	11.7	19.5	100
Additional annual growth rate (%)						
Scenario 1						
Malawi	0.4	0.4	1.0	1.0	0.7	0.8
Mozambique	0.4	0.6	0.2	0.6	0.0	0.2
Zambia	0.8	0.8	0.7	1.3	1.0	0.9
Scenario 4						
Malawi	3.1	6.7	1.4	2.8	0.4	2.0
Mozambique	2.4	11.7	0.2	0.1	-0.4	1.0
Zambia	2.7	9.7	1.3	1.6	1.0	2.8
Scenario 5						
Malawi	0.7	0.6	1.3	10.6	0	1.5
Mozambique	0.5	0.8	0.2	11.6	-0.6	0.4
Zambia	0.9	1.0	1.3	8.5	0.3	1.8

a/ Roots and tubers and fruits and vegetables.
b/ Fruits and vegetables, oilseeds, and cotton.
c/ Tobacco, tea, coffee, and cocoa .
Source: CGE model results.

sectors.[3] Table 7 summarizes the growth effects in five aggregate agricultural sub-sectors and their contributions to overall economic growth in Malawi, Mozambique, and Zambia. Growth in staple crops (mainly produced for domestic markets) contributes the most to overall economic growth, due to the size of the sector and its high growth rates. For example, grain and other staple crops account for more than 10 percent of GDP in the three countries, and growth in these sectors contributes to 23–31 percent of overall GDP growth in the three countries.

B. Agriculture has strong growth linkages to non-agriculture

In the second group of scenarios, we turn our attention to the low-income southern African countries' own growth engines. Scenario 2 focuses on the maize and livestock sectors, while Scenario 3 analyzes the impact of growth in the non-traditional export sector. In these scenarios, we exogenously increase TFP of these agriculture sub-sectors by 4.5 percent in the three low-income countries, while

there is no additional growth in the other sectors in these three countries and no additional growth in any sector of other southern African countries. By applying the same TFP growth rate at the sectoral level for the three countries, we are able to capture differences in the linkage and scale effects of those sectors in each country's economy.

We focus first on linkage effects by calculating GDP growth multipliers, derived from TFP shocks in corresponding agricultural sub-sectors[4]. We define the multipliers as the increase in total GDP, divided by the increase in the shocked sector's total value-added, both measured at the initial (base-year) level of prices. In general, multipliers derived using CGE models are relatively smaller than the standard fixed-price multipliers (see Dorosh and Haggblade (2003) for a comparison of CGE and fixed-price multipliers). Our model simulation results show strong multiplier effects of growth in both staple food (maize and livestock) and exportable agriculture (fruits and vegetables, oilseeds, and cotton): 1.00 unit of increase in maize and livestock's value-added generates 1.23 to 1.36 units of increase in total GDP in Malawi, Mozambique and Zambia. An increase of 1.00 unit in fruits and vegetables, oilseeds, and cotton value added generates 1.26 to 1.66 units of increase in total GDP in the three countries.

Multiplier analysis cannot reveal the scale effect, as a larger sector can have a stronger impact on overall growth, even though the multiplier may not be big. For this reason we also look at the aggregate effect of growth in an agricultural sub-sector on total GDP, agricultural GDP, agricultural exports and imports, and other macroeconomic indicators. Scenarios 2 and 3 in Table 6 show that a combined 4.5 percent growth in maize and livestock productivity results in 0.24–0.48 percent and 1.68–2.44 percent annual growth in total GDP and agricultural GDP respectively in the three countries. Moreover, a productivity shock of the same magnitude applied to non-traditional export crops generates a much smaller effect on both total GDP and agricultural GDP. As expected, maize and livestock growth has a larger impact on domestic production and import substitution, with maize imports falling by 12.2–38.7 percent and livestock imports falling by 8.6–10.8 percent in the three countries, resulting in a decline in total agricultural imports of 0.8–2.7 percent. On the other hand, the major impact of increased productivity in non-traditional export crops is on exports, which increase by 2.3–2.7 percent per year in Mozambique

[4]See Bell and Hazell (1980) for an early methodological discussion of alternative multiplier models used in growth linkage analysis, and the discussion of Haggblade, Hammer, and Hazell (1991) on the improvement in the multiplier models with limited price endogeneity.

and Zambia.

The expansion of grain and livestock output reduces domestic food prices at an annual rate of 0.76 percent in Mozambique and 1.33 and 0.91 percent in Malawi and Zambia respectively. This not only explains the significant increases in food consumption but also shows the existence of demand constraints to the expansion of grain production. With no simultaneous growth in income generated outside the grain sector and significant substitution for imports through improved import channels, productivity growth in the grain sector can cause a shift in domestic terms of trade against agriculture, negating the income benefit of productivity improvement (Adelman 1984).

C. Growth in middle-income countries can help low-income countries overcome their domestic demand constraints for grains

Scenarios 4 and 5 combine non-agricultural TFP growth in middle-income countries (Botswana, the rest of SACU, and the rest of the southern African region, representing Mauritius and Angola) with agricultural TFP growth in the three low-income countries. In both scenarios, South Africa's GDP is targeted to grow at the same rate as in Scenario 1 (4.5 percent annually). Growth in Botswana is targeted to be 7 percent, while growth in the rest of SACU is 6 percent, close to the average historical growth rates of these countries. The rest of the SADC region is targeted to grow at 7 percent too, based on the economic recovery process in Angola. In all these countries, growth is driven by TFP increases in the non-agricultural sectors, while for the three low-income countries, growth is driven by TFP increases in maize and livestock (in Scenario 4) or in non-traditional export crops (in Scenario 5). Similar to Scenarios 2 and 3, an annual growth rate of 4.5 percent is assumed for TFP in the selected agricultural sub-sectors.

Increased economic growth in middle-income countries enhances the impact of productivity growth on farm income. In Scenario 4, real agricultural GDP per capita grows at 2.5, 3.0, and 3.4 percent in Mozambique, Zambia, and Malawi, respectively, much higher than the corresponding growth rates obtained in Scenario 2 (Table 6). Economic growth in the middle-income countries also boosts the impact of productivity growth in non-traditional exports (Scenario 5). GDP growth in Malawi, Mozambique, and Zambia is 7 to 10 times larger in this scenario than in scenario 3 in which agricultural export growth is stimulated by improving productivity in these countries alone. At the sub-sectoral level, 4.5 percent productivity growth in maize and livestock (scenario 4) results in 3.1 percent

growth of maize production in Malawi and only 2.4 percent in Mozambique and 2.7 percent in Zambia. Increased efficiency in maize and livestock production enhance growth in the livestock sector with rates that go from 6.7 in Malawi to 11.7 in Mozambique.

As expected, growth in non-traditional export sectors (scenario 5) has a significant impact on agricultural exports (Table 8). In Mozambique, for example, total agricultural exports grow at an annual rate of 2 percent in Scenario 5, compared with only 0.5 percent in Scenario 4, where productivity growth in the maize and livestock sector is assumed to be similar. Fruits and vegetables show the highest export growth rate in Mozambique, while oilseed exports increase more rapidly in Zambia. However, the major contribution to agricultural export growth in both countries does not come from growth in fruits and vegetables or oilseeds, given their small share in total exports, but from cotton. This crop could offer export opportunities for Zambia, as cotton is still considered a non-traditional export crop there. Cotton's share of agricultural exports is 11 percent in Zambia, compared with more than 22 percent in Mozambique. These results confirm the potential that these countries have to diversify their exports by expanding non-traditional crops, but they also show the limitations of these crops as growth engines in the agricultural sector, due to their small share of agriculture.

Table 8. Growth in Non-traditional Exports in Scenario 5

Country	Fruits and vegetables	Oilseeds	Cotton
Malawi			
Share in total exports (%)	1.9	0.4	1.2
Additional annual growth in exports (%)	22.3	35.1	24.5
Contribution to agricultural export growth (%)	89.1	29.6	57.9
Mozambique			
Share in total exports (%)	10.2	5.7	22.2
Additional annual growth in exports (%)	20.7	12.7	14.9
Contribution to agricultural export growth (%)	39.5	13.7	62.2
Zambia			
Share in total exports (%)	9.3	0.7	10.6
Additional annual growth in exports (%)	16.8	38.0	21.6
Contribution to agricultural. export growth (%)	43.6	7.7	63.7

Note: Sum of the contributions is greater than 100 because of declines in the other sectors' exports.
Source: CGE model results.

V. Conclusions

This study has identified several characteristics of southern Africa that provide opportunities for agricultural growth through exploitation of regional linkages. First, southern Africa is the only region in the African continent with a number of middle- and low-income countries in close proximity to each other. Potential growth linkages between these economies could favor regional production and trade. In particular, the agricultural sector in low-income countries can benefit from the regional dynamics afforded by their more advanced neighboring countries. Second, non-exploited agricultural potential can also generate regional growth opportunities for low-income countries. This is due to the historically stagnant or even declining levels of agricultural productivity and the fact that low-income southern African countries have relatively favorable agricultural potential and conditions. Third, potentially strong trade and investment linkages in the region can contribute to agricultural growth in low-income countries. By applying a regional general equilibrium model to southern Africa, we were able to analyze the effects of the region's unique characteristics on the growth choices of low-income countries.

Results show that growth of the middle-income countries, such as South Africa, has a significant effect on low-income countries' economies, increasing GDP and real agricultural income, stimulating domestic agricultural production and exports, and reducing imports. Agricultural productivity growth, however, is the key for low-income countries to take advantage of South Africa's growth. Productivity growth in grain and livestock production in low-income countries generates more growth in GDP and food consumption in these countries than growth in non-traditional export crops. Unlike other regions where growth in grain production is likely to be constrained by domestic demand, growing middle-income economies in southern Africa provide additional demand for grains and livestock, slowing down the decline in grain prices resulting from increased production in low-income countries. Given the gap that currently exists in maize and livestock production between low- and middle-income countries, there is potential in low-income countries to accelerate growth of agricultural production by promoting productivity growth in their maize and livestock sectors. Our results also show the potential that these countries have to diversify their exports by increasing productivity of non-traditional crops. However, these crops can play a limited role as growth engines in the agricultural sector due to their small share in agriculture.

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Appendix I: Data Aggregation

Table A.1 Country and Sector Aggregation in the Model

Country/region groups	
1. Botswana	12. Rest of sub-Saharan Africa
2. Madagascar	13. Morocco
3. Malawi	14. Tunisia
4. Mozambique	15. Rest of North Africa
5. Republic of South Africa	16. China
6. Tanzania	17. India
7. Uganda	18. Rest of Asia
8. Zambia	19. The United States
9. Zimbabwe	20. European Union and European Free Trade Area
10. Rest of Southern African Custom Union	21. Other Europe
11. Rest of southern Africa	22. Rest of world
Sector/commodity groups	
1. Paddy rice	18. Vegetable oils and fat
2. Wheat	19. Dairy products
3. Other grains (mainly maize)	20. Processed rice
4. Exportable vegetables and fruits	21. Sugar
5. Domestic vegetables and fruits	22. Processed food products
6. Oilseeds	23. Beverages and tobacco products
7. Sugar cane sugar beet	24. Energy products
8. Plant-based fibers (mainly cotton)	25. Minerals
9. Exportable other crops (mainly tree crops)	26. Textile and clothing
10. Domestic other crops	27. Heavy industrial products
11. Bovine cattle, sheep, goats, and horses	28. Machinery and equipment
12. Animal products	29. Electricity, water, and urban utility supply
13. Raw milk	30. Wholesale and retail trade services
14. Forestry	31. Transportation
15. Fishing	32. Water and air transportation
16. Bovine cattle, sheep and goat meat products	33. Other services
17. Other meat products	34. Public administrative, education, and health services

Appendix II: Equations and Variables in the CGE Model

The subscripts *i* and *j* in the following variables and parameters refer to commodity/sector set, in which '*otp*' is a specific elemement to represent transport sector, *f* refers to factors, and *r* and *s* refer to country/regional group set.

Variables

A. Production side

$PX_{i,r}$	Producer price of good *i* in country *r*
$PVA_{i,r}$	Value added price of good *i* in country *r*
$WF_{f,r}$	Returns to factor *f* in country *r*
$X_{i,r}$	Output of sector *i* produced in country *r*
$FD_{f,i,r}$	Factor demand of *f* by sector *i* in country *r*
$FS_{f,r}$	Total supply of factor *f* in country *r*
$INTD_{i,r}$	Intermediate demand of good *i* in country *r*

B. Demand side

YH_r	Household total income in country *r*
$GOVREV_r$	Government revenue in country *r*
$ZTOT_r$	Total investment in country *r*
$GOVTRAN_r$	Government transfers to household in country *r*
$CD_{i,r}$	Household demand of good *i* in country *r*
$GD_{i,r}$	Government demand of good *i* in country *r*
$INVD_{i,r}$	Investment demand of good *i* in country *r*

C. Trade

$PWM_{i,r,s}$	c.i.f. price of good *i* for country *s* imported from *r*
$PWE_{i,r,s}$	f.o.b. price of good *i* for country *r* exporting to country *s*
$PM_{i,r,s}$	Import price of good *i* in country *s*'domestic market and imported from country *r*
$PE_{i,r,s}$	Export price of good *i* at the border of country *r* and exporting to country *s*
$PMM_{i,r}$	Armington price of import-composite good *i* for country *r*
$PEE_{i,r}$	CET price of export-composite good *i* in country *r*
$PD_{i,r}$	Price for output *i* domestically produced and consumed in country *r*
$PC_{i,r}$	Armington price of composite good *i* in country *r*

$E_{i,r,s}$ Good *i* exporting from country *r* to country *s*

$M_{i,r,s}$ Good *i* imported by country *s* from country *r*

$EE_{i,r}$ Export-composite good *i* for country *r*

$MM_{i,r}$ Import-composite good *i* for country *r*

$DC_{i,r}$ Output *i* domestically produced abd consumed in country *r*

$CC_{i,r}$ Composite good *i* for country *r*

$TRANSPR_{i,r,s}$ International transport cost for good *i* shiping from country *r* to *s*

$TSPRM_{i,r,s}$ Transport cost for good *i* imported by country *s* from country *r* occurred in country *s*' domestic markets

$TSPRE_{i,r,s}$ Transport cost for good *i* exporting from country *r* to *s* and occurred in country *r*'s domestic markets

D. Macro closures

$\overline{FSAVE_r}$ Fixed net foreign savings (trade deficits) of country *r*

$\overline{GOVEXPS_r}$ Fixed government total expenditure in country *r*

Parameters

A. Defined substitution elasticities

$\sigma^c_{i,r}$ Armington elasticity of substitution between domestic and import-composite good *i* in country *r*

$\sigma^m_{i,r}$ Armington elasticity of substitution between imports of good *i* in country *r* imported from different exporting countries

$\sigma^t_{i,r}$ CET elasticity of substitution between domestic and export-composite good *i* in country *r*

$\sigma^e_{i,r}$ CET elasticity of substitution between exports of good *i* in country *r* exporting to different importing countries

$\sigma^x_{i,r}$ Elasticity of substitution in CES value-added production function for sector *i* in country *r*

B. Computed substitution elasticities, share and shift parameters

$\beta^c_{i,r}$ Share parameter in household's demand function for good *i* in country *r*

$\beta^g_{i,r}$ Share parameter in government's demand function for good *i* in country *r*

$\beta^x_{i,r}$ Share parameter in investment demand function for good *i* in country *r*

$\alpha_{f,i,r}$ Share parameter in value-added production function of sector *i* for factor *f* in country *r*

$\delta^m_{i,r,s}$ Share parameters in Armington import function for good *i* imported by

country *s* from *r*

$\delta^{e}_{i,r,s}$ Share parameters in CET export function for good *i* exported by country *r* to *s*

$\delta^{t}_{i,r,s}$ Share parameters in CET function for export-composite good *i* in country *r*

$\delta_{i,r}$ Share parameters in Armington function for import-composite good *i* imported in country *r*

$\gamma_{i,r}$ Subsistence parameter in Stone-Geary utility function

$\Lambda^{m}_{i,r}$ Shift parameter for import good *i* by country *r* in Armington import function

$\Lambda^{c}_{i,r}$ Shift parameter for import-composite good *i* in in Armington function in country *r*

$\Lambda^{e}_{i,r}$ Shift parameter for export good *i* in country *r* in CET export function

$\Lambda^{t}_{i,r}$ Shift parameter for export-composite good *i* in country *r* in CET function

$\Lambda^{x}_{i,r}$ Shift parameter for sector *i* in country *r* in CES value-added production function

C. Other computed parameters

$\phi_{i,r,s}$ International transport margin for good *i* exported from country *r* to *s*

$\phi^{m}_{i,r,s}$ Transport margin for imports of good *i* paid to importing country *s*' domestic transport firm and imported from country *r*

$\phi^{e}_{i,r,s}$ Transport margin for exports of good *i* paid to exporting country *s*' domestic transport firm and imported from country *r*

$io_{i,j,r}$ Input-output coefficient for good *i* used in sector *j* in country *r*

$xtaxr_{i,r,s}$ Export tax rate on good *i* in country *r* exporting to *s*

$mtaxr_{i,r,s}$ Import tax rate on good *i* in country *s* imported from *r*

$ptaxr_{i,r}$ Producer tax on good *i* in country *r*

$ctaxr_{i,r}$ Commodity sales tax rate on good *i* in country *r*

$hsaver_{r}$ Household saving rates in country *r*

exr_{r} Nominal exchange rate in country *r*

Figure A.1. Illustration of the CGE model: within country flows

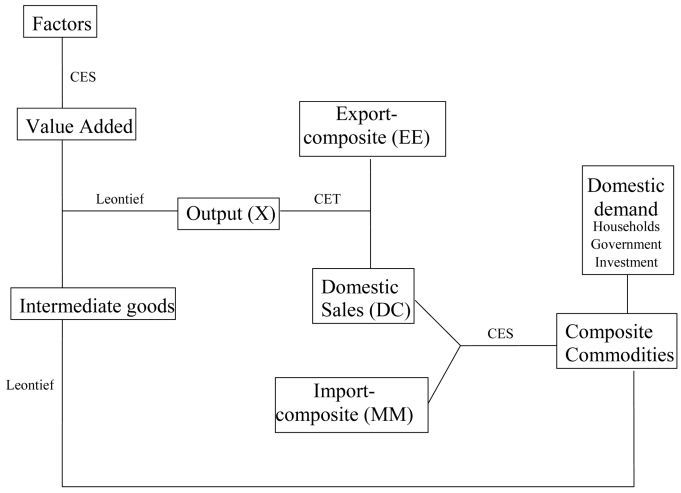
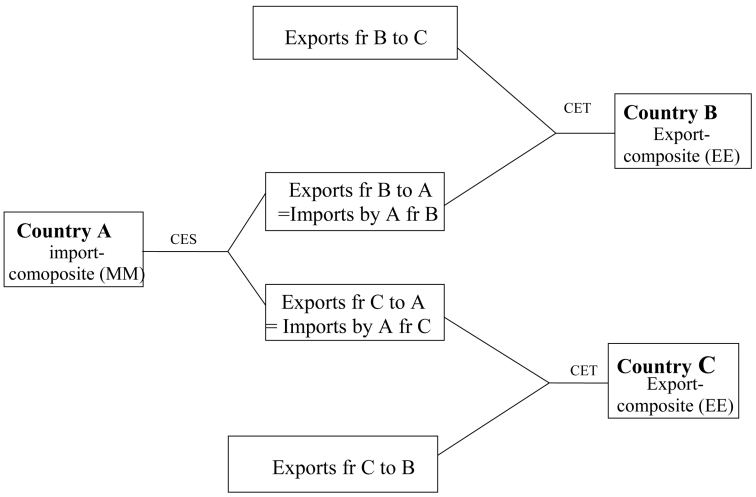


Figure A.2. Illustration of the CGE model: trade flows between countries



Model equations

A. Relationship between CIF and FOB prices

(1) $$PWM_{i,s,r} = (1 + TRANSPR_{i,s,r}) \times PWE_{i,s,r}$$

(1a) $$TRANSPR_{i,s,r} = \phi_{i,s,r} \times PWE_{i,s,r}$$

B. Production and input demand

CES value-added function

$$PVA_{i,r} = (\Lambda^{x}_{i,r}) \times \left[\sum_{f} (\alpha^{\sigma^{x}_{i,r}}_{f,i,r} \times WF^{1-\sigma^{x}_{i,r}}_{f,r}) \right]^{\frac{1}{(1-\sigma^{x}_{i,r})}} \tag{2}$$

Factor demand

$$FD_{f,i,r} = (\Lambda^{d}_{i,r})^{\sigma^{x}_{i,r}-1} \times \left(\frac{PVA_{i,r} \times \alpha_{f,i,r}}{WF_{f,r}} \right) \times X_{i,r} \tag{3}$$

Intermediate demand

$$INTD_{i,r} = \sum_{i'} (io_{i,i',r} \times X_{i,r}) \tag{4}$$

Relationship between value-added and output prices

$$\frac{PX_{i,r}}{(1+ptaxr_{i,r})} = PVA_{i,r} + \sum_{i'} [o_{i,i',r} \times PC_{i',r} \times (1+ctaxr_{i',r})] \tag{5}$$

C. Imports and exports

Armington import function for composite goods

$$PC_{i,r} = (\Lambda^{c}_{i,r})^{-1} \times (\delta^{\sigma^{c}_{i,r}}_{i,r} \times PMM^{1-\sigma^{c}_{i,r}}_{i,r} + (1-\delta_{i,r})^{\sigma^{c}_{i,r}} PD^{1-\sigma^{c}_{i,r}}_{i,r})^{\frac{1}{(1-\sigma^{c}_{i,r})}} \tag{6}$$

Demand for import-composite goods

$$MM_{i,r} = (\Lambda^{c}_{i,r})^{\sigma^{c}_{i,r}-1} \times \left(\frac{\delta_{i,r} \times PC_{i,r}}{PMM_{i,r}} \right) \times CC_{i,r} \tag{7}$$

Demand for domestically produced goods

$$DC_{i,r} = (\Lambda^{c}_{i,r})^{\sigma^{c}_{i,r}-1} \times \left(\frac{(1-\delta_{i,r}) \times PC_{i,r}}{PD_{i,r}} \right)^{\sigma^{c}_{i,r}} \times CC_{i,r} \tag{8}$$

Armington function for import-composite goods

$$PMM_{i,r} = (\Lambda^{m}_{i,r})^{-1} \times \left[\sum_{s} \left((\delta^{m}_{i,s,r})^{\sigma^{m}_{i,r}} \times PM^{1-\sigma^{m}_{i,r}}_{i,s,r} \right) \right]^{\frac{1}{1-\sigma^{m}_{i,r}}} \tag{9}$$

Import price in domestic markets

(10) $$PM_{i,s,r} = (1 + mtaxr_{i,s,r}) \times EXR_r \times (1 + TSPRM_{i,s,r,s}) \times PWM_{i,s,r}$$

(10a) $$TSPRM_{i,s,r} = \phi_{i,s,r} \times PX_{otp',r}$$

Imports demand

(11) $$M_{i,s,r} = (\Lambda^m_{i,r})^{\sigma^m_{i,s}-1} \times \left(\frac{PMM_{i,r} \times \delta^m_{i,s,r}}{PM_{i,s,r}}\right) \times MM_{i,r}$$

CET function for export-composite goods

(12) $$PX_{i,r} = (\Lambda^t_{i,r})^{-1} \times \left((\delta^t_{i,r})^{-\sigma^t_{i,r}} \times PEE^{1+\sigma^t_{i,r}}_{i,r} + (1 - \delta^t_{i,r})^{-\sigma^t_{i,r}} PD^{1+\sigma^t_{i,r}}_{i,r}\right)^{\frac{1}{1+\sigma^t_{i,r}}}$$

Supply of export-composite goods

(13) $$EE_{i,r} = (\Lambda^t_{i,r})^{-(1+\sigma^t_{i,r})} \times \left(\frac{\delta^t_{i,r} \times PX_{i,r}}{PEE_{i,r}}\right) \times X_{i,r}$$

Supply to domestic markets

(14) $$DC_{i,r} = (\Lambda^t_{i,r})^{-(1+\sigma^t_{i,r})} \times \left(\frac{(1 - \delta^t_{i,r}) \times PX_{i,r}}{PD_{i,r}}\right) \times X_{i,r}$$

CET function of export-composite goods

(15) $$PEE_{i,r} = \Lambda^e_{i,r} \times \left((\delta^e_{i,r})^{-\sigma^e_{i,r}} \times PE^{1+\sigma^e_{i,r}}_{i,r,s}\right)^{\frac{1}{1+\sigma^e_{i,r}}}$$

Export price in domestic markets

(16) $$PE_{i,r,s} = \frac{(1 - xtaxr_{i,r,s}) \times EXR_r}{(1 + TSPRE_{i,r,s})} \times PWE_{i,r,s}$$

(16a) $$TSPRE_{i,r,s} = \phi^e_{i,r,s} \times PX_{otp',r}$$

Export supply

(17) $$E_{i,r,s} = (\Lambda^e_{i,r})^{-(1+\sigma^e_{i,r})} \times \left(\frac{PEE_{i,r} \times \delta^e_{i,r,s}}{PE_{i,r,s}}\right)^{-\sigma^e_{i,r}} \times EE_{i,r}$$

Identification between imports by country *r* from *s* and exports from country *s* to *r*

$$M_{i,s,r} = E_{i,s,r} \tag{18}$$

D. Final demand and income

Household income

$$YH_r = \sum_f \sum_i WF_{f,r} \times FD_{f,i,r} \times GOVTRAN_r \tag{19}$$

Household consumption demand

$$CD_{i,r} = \frac{\beta^c_{i,r} \times \left(YH_r \times (1 - hsaver_r) - \sum_{i'} PCT_{i',r} \times \gamma_{i,r} \right)}{PC_{i,r} \times (1 + ctaxr_{i,r})} + \gamma_{i,r} \tag{20}$$

Government revenue

$$\begin{aligned} GOVREV_r = & \sum_i \sum_s [xtaxr_{i,r,s} \times exr_r \times PWE_{i,r,s} \times E_{i,r,s}] + \\ & \sum_i \sum_s [mtaxr_{i,s,r} \times exr_r \times PWM_{i,s,r} \times M_{i,s,r}] + \\ & \sum_i [PC_{i,r} \times (1 + ctaxr_{i,r}) \times CC_{i,r}] + \\ & \sum_i \{[(ptaxr_{i,r}) / (1 + ptaxr_{i,r})] \times PX_{i,r} \times X_{i,r}\} \end{aligned} \tag{21}$$

Government final demand

$$GD_{i,r} = \frac{\beta^g_{i,r} \times \overline{GOVEXPS_r}}{(PC_{i,r} \times (1 + ctaxr_{i,r}))} \tag{22}$$

Government transfers

$$GOVTRAN_r = GOVREV_r - \overline{GOVEXPS_r} \tag{23}$$

Investment demand

$$INVD_{i,r} = \frac{\beta^z_{i,r} \times ZTOT_r}{(PC_{i,r} \times (1 + ctaxr_{i,r}))} \tag{24}$$

E. Equilibrium conditions

Commodity markets

(25) $$CC_{i,r} = CD_{i,r} + GD_{i,r} + INVD_{i,r} + INTD_{i,r}$$

Factor market

(26) $$\sum_{i} FD_{f,i,r} = FS_{f,r}$$

Foreign savings

(27) $$\overline{FSAVE_r} = \sum_{i}\sum_{s}(PWM_{i,s,r} \times M_{i,s,r}) - \sum_{i}\sum_{s}(PWM_{i,r,s} \times E_{i,r,s})$$