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THE ROLE OF COCOA IN GHANA'S FUTURE DEVELOPMENT

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THE GHANA STRATEGY SUPPORT PROGRAM (GSSP)
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SUMMARY

The recent surge in world commodity prices might alter the role of traditional export crops in African economies. While export crops have traditionally been important sources of foreign exchange earnings and government revenues, Ghana is an exceptional case, where a combination of favorable external conditions and internal reforms have made cocoa the driver of growth and poverty reduction. Cocoa's share of agricultural GDP has been increasing rapidly and existing yield gaps and the prospects of continued high world commodity prices suggest further growth potential. We find that increasing cocoa production by around 60,000 tons per annum is needed to support Ghana reaching its middle-income country target. However, cocoa's poverty-growth elasticity is low, thus implying that further growth is unlikely to lead to the large reductions in poverty experienced in the past. Finally, we show that, even with complimentary growth in other sectors, cocoa will continue to dominate agricultural exports over the medium term and that structural diversification remains a key challenge for Ghana.

Key words: Traditional export crops, cocoa, growth, poverty, Africa, Ghana

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I. INTRODUCTION

Traditional export crops have played an important role in the development of many African countries by generating foreign exchange earnings, government revenues, and household incomes. Dependence on a few export commodities has often made these countries vulnerable to international price volatility, however, and a continued deterioration of agricultural commodities' terms of trade has reinforced the divergence in economic development between primary-commodity-producing countries and manufacturing and service exporters (Wilson 1984; UNCTAD 2005). Nevertheless, rapid and sustained global growth driven by emerging economies has started to reverse this trend. World prices of agricultural export goods and food have hit record highs, and there are indications that this demand-driven period of high prices might continue over the next decade (IMF 2007; von Braun, 2007; World Bank 2007). In addition, macroeconomic and governance indicators in many African countries have improved, and a renewed focus on agricultural investments and market-based price-risk-management strategies has the potential to reduce supply constraints, price volatility and to support agricultural growth (Byerlee, Jayne, and Myers 2006; World Bank 2007).

Ghana is a prime example, where favorable external conditions and internal reforms have led to a surge in traditional exports. Ghana has regained its top position among the world's leading cocoa producers and exporters, and the sector has played an important role in the nation's recent economic growth (McKay and Aryteey 2005; Bogetic et al. 2007). In light of these circumstances, the Government of Ghana has extended its development vision and recently declared the goals of reaching middle-income (MIC) status by 2015 and further reducing the number of poor beyond the level required by the first Millennium Development Goal. This will require doubling per capita income from the current US$450 to US$1,000 by 2015. While the Government of Ghana stresses the need for diversifying the nation's economic structure, it also emphasizes the important role of the cocoa sector and has set the target of achieving one million metric tons of cocoa output by 2010 (NDPC 2006; IITA 2007).

Skeptics argue that a focus on traditional export crops might keep Ghana caught in a resource trap and prevent the structural diversification of the economy that many other countries have experienced on their way to MIC status. There are also

doubts about the sustainability of cocoa growth in Ghana, because this growth has been driven by land expansion and increased use of labor rather than by productivity growth (Gockowski 2007; Vigneri 2007). Further, while the Cocoa Board is often given credit for its important role in the recent surge in cocoa production, there are indications that the recent boom has been a result of high price incentives rather than the removal of constraints to production and productivity-enhancing measures (Teal and Zeitlin 2006). Critics also question the efficiency of the Cocoa Board's operations, expenditures for which accounted for 85 percent of total 2006 agricultural expenditures in Ghana.

However, there are several indications that cocoa can continue to play an important role in Ghana's economic growth toward MIC status. First, international cocoa prices are likely to remain high (World Bank 2007). Second, cocoa yields in Ghana are well below international averages, suggesting potential for productivity-driven growth (FAO 2005; ICCO 2007). Third, new scientific evidence emphasizes health benefits for cocoa consumers, potentially further boosting demand (ICCO 2007). Finally, the Government of Ghana is expected to continue its support to the cocoa sector, and there are indications that the partial liberalization of Licensed Buying Companies will continue to contribute to output and productivity growth (Varangis and Schreiber 2001; Zeitlin 2005).

Given cocoa's large role in Ghana's economy and the involvement of many small farmers in its production, it is the objective of this paper to analyze what role cocoa might (have to) play in Ghana's efforts to reach MIC status, accelerate growth, and reduce poverty. We use an economy-wide model to synergize cocoa growth projections with growth in other sectors and evaluate their combined effects. The strength of this approach is to take into account linkages between sectors and resource competition between different factors of production, between domestic demand and trade, and between cocoa and non-cocoa sectors. After reviewing the role of the cocoa sector in Ghana's recent growth and poverty reduction in Section 2, we analyze, in Section 3, the potential role of cocoa in achieving MIC status and additional poverty reduction. Challenges facing the cocoa sector's further growth will conclude the paper.

II. THE ROLE OF COCOA IN RECENT GROWTH AND POVERTY REDUCTION IN GHANA

Overview

Global demand for cocoa increased by about 17 percent between 2001/2 and 2005/6, and in response to this, cocoa production hit an all time high of 3.6 million metric tons in 2005/6 (ICCO 2007). West African countries, including Ghana, accounted for most of this growth, together accounting for more than 70 percent of total world cocoa production in 2006 (ICCO 2007). Moreover, Ghana, Nigeria, and Cameroon have all set ambitious targets for further raising cocoa production. Ghana plans to increase its production by 100,000 tons per annum, while Nigeria's and Cameroon's targets are 40,000 t and 10,000 t p.a., respectively (IITA 2007). In recent years, Ghana has been the most successful of all cocoa exporters. Higher producer prices, partial liberalization of internal marketing, establishment of a price stabilization system, government-backed rehabilitation programs, spraying programs, fertilizer credits, improvements in extension systems, and the privatization of input distribution may have contributed to growth in the cocoa sector (ICCO 2007; Laven 2007). The next section reviews Ghana's recent impressive growth performance in this sector and analyzes this growth's impact on the poor.

Cocoa production and exports

Cocoa has historically been a key economic sector and a major source of export and fiscal earnings (Bulir 1998; McKay and Arytee 2005). In recent years, cocoa production more than doubled, from 395,000 tons in 2000 to 740,000 tons in 2005, contributing 28 percent of agricultural growth in 2006—up from 19 in 2001 (Bogetic et al. 2007). Earlier evidence of the relatively low supply elasticities of cocoa producers in Ghana makes this development even more impressive (Abdulai and Rieder 1995). The boost in production has led to an increase of cocoa's share in agricultural GDP from 13.7 percent in 2000-2004 to 18.9 percent in 2005/2006. Producer prices rose by about 260 percent between 2000 and 2006 (Figure 1), largely driven by the surge in world (FOB) prices before 2003 and the reduced marketing margins since then. Together, both developments have led to an increase in producers' share of FOB prices from about 50 percent in 2002 to 75 percent in 2005/2006. Earlier studies find a strong correlation between producer prices and the supply of

cocoa in Ghana (Abdulai and Rieder 1995), and the recent price increase is likely to have made a significant contribution to the strong cocoa performance.[1]

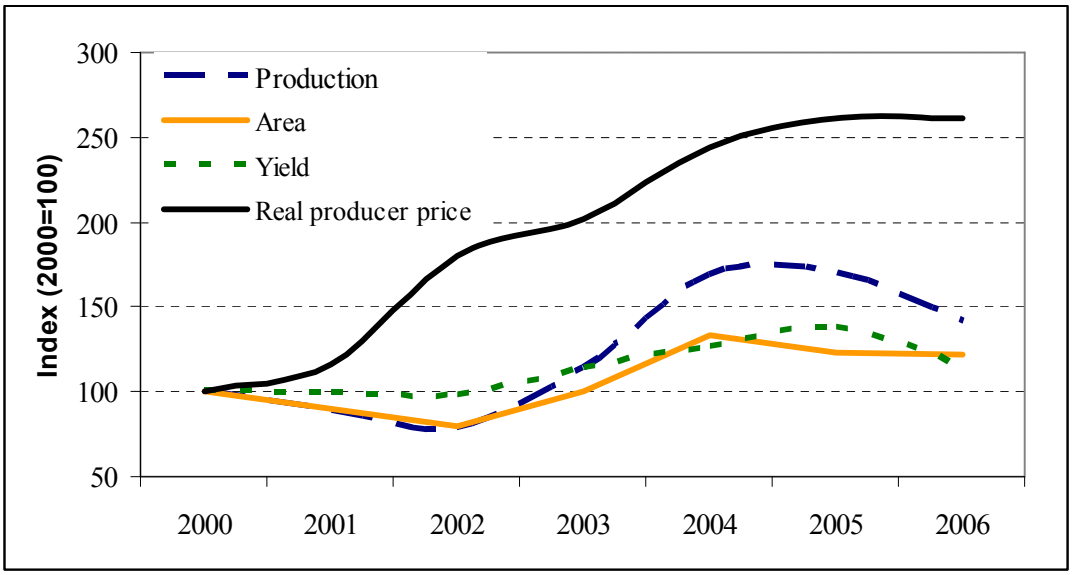
Growth in yields, almost 40 percent between 2000 and 2004, has slowed in recent years. The Cocoa Board's promotion of technological packages and the increased access to credit, together with a partial liberalization of cocoa marketing, are likely to have raised productivity. Vigneri identifies higher input of family labor into production and favorable weather conditions as major causes for yield increases (Vigneri 2007). Despite the recent increase in yields, huge potential exists for further improvements: FAO and the Ministry of Food and Agriculture (MOFA) estimate that achievable yields for cocoa are around 1-1.5 tons per hectare, more than double the average yields in 2005 (FAO 2005; MOFA 2007).[2]

Area expansion has contributed to output growth from 2002 to 2004, but the area planted has since declined, from two million hectares in 2004 to 1.8 million hectares in 2006, about 25 percent of cultivated land in Ghana (MOFA 2006; Cocoa Board 2007). A comparison of land currently devoted to cocoa production and land that is suitable for the production of cocoa indicates that future growth in production through area expansion will be limited (Figures A1 and A2 in appendix). Current cocoa production is concentrated in areas that are "very suitable" or "suitable," but also extends to areas only "moderately suitable." Even moderately suitable land is limited and the majority of remaining land, especially in the North, is not suitable for cocoa production.

[1] Another factor that might have contributed to the surge in cocoa "production" could be smuggling from neighboring countries. It has also long been argued that existing price differentials between Ghana and its neighbors encourage the smuggling of cocoa, leading to inflated production numbers (Bulir 2002).

[2] Based on Appiah, Ofori-Frimpong, Afrifa 2000.

Figure 1. Trends of major cocoa indicators in Ghana (Index 2000=100)



Source: Authors' calculations based on data from Cocoa Board 2007, FAO 2007, IMF 2007.

Cocoa exports, the second most important export good for Ghana, have more than doubled between 2002 and 2006. In 2005, cocoa beans (24.3 percent) and cocoa products (3.8 percent) accounted for about 28 percent of total exports, slightly behind gold and significantly behind forestry products (15 percent) (BoG 2007). Cocoa accounts for about half of agricultural exports, including forestry and fishery. In comparison, the two major non-traditional agricultural export commodities, palm oil and fruits, together account for only about 4 percent of total agricultural exports. Despite cocoa's rapid export growth, Ghana's trade deficit has widened to about 28 percent of GDP, because of rapidly rising imports.

Linkages of the Cocoa Sector

Linkages of cocoa production to other sectors of the economy, including cocoa processing (cocoa milling and cocoa butter production), other food industries (beverages, bakery, chocolate products), and trade, transportation, and other marketing activities, offer additional potential for growth. However, the share of low-income, cocoa-producing countries in cocoa processing remains low. Africa accounts for only 15 percent of world grindings in 2005/06, while Europe slightly increased its share in world grindings from 41 percent in 2004/05 to 42 percent in 2005/06 (ICCO 2007). But Côte d'Ivoire and Malaysia are exceptions and remained the top processing countries among the cocoa-producing countries, grinding about 48 percent at origin. The share of cocoa processed in Ghana, however, remains small and below

the African average, ranging from 8 to 12 percent in recent years. Also, the domestic food industry that uses cocoa as an input remains relatively small. As a result, value added to cocoa products is low, limiting its contribution to overall economic growth. However, there are encouraging signs and potentials for expansion. The value of processed cocoa-based exports in Ghana has gone up from US$83.6 million in 2004 to US$152.9 million in 2006 (CEPS 2006).

Ghana continues to levy an export tax on cocoa that contributes directly to government incomes. The importance of this income source has declined, however, coming down from an average of 16 percent in the 1960s and 12 percent in the 1990s to about 5 percent in 2005 (ISSER 2001; BoG 2007). Additional cocoa-related income tax revenues come from the nearly half-million cocoa-producing households.

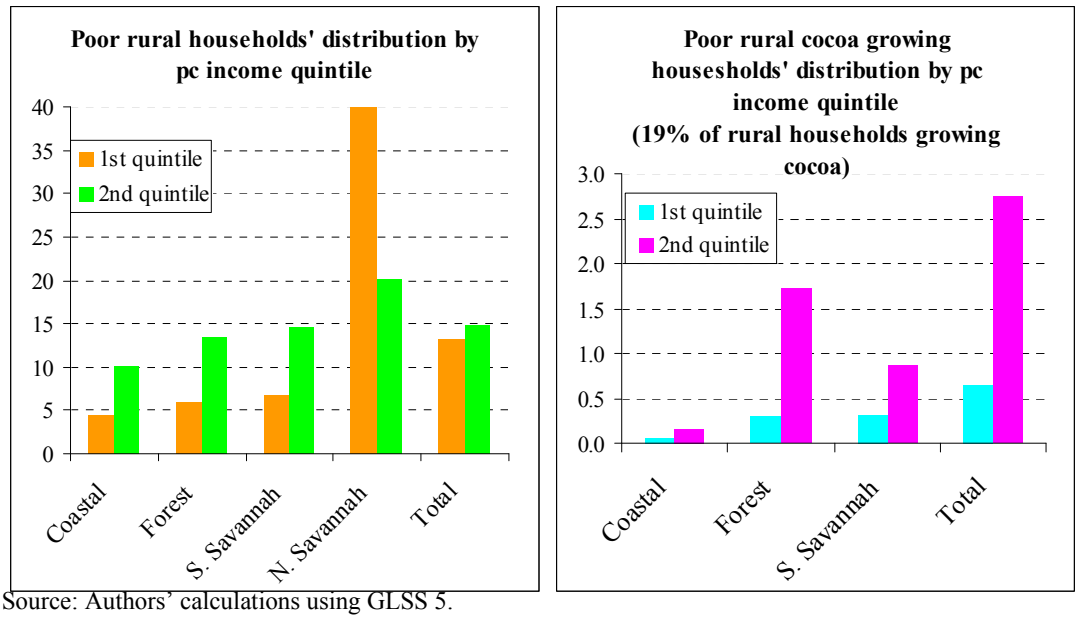
Role of cocoa in household incomes and poverty status

The national poverty rate in Ghana has fallen from 51.7 in 1991/92 and 39.5 percent in 1998/1999 to 28.5 percent in 2005/2006. Both rural and urban poverty declined by about 10 percentage points, to 10.8 and 39.2 percent, respectively. Poverty among cocoa farmers has also declined significantly, and cocoa growth has been more pro-poor than growth in other sectors. While the poverty rate used to be 60.1 percent among cocoa farmers in 1991/92, it has declined significantly and is now 23.9 percent, or 112,000 cocoa-farming households (Coulombe and Wodon 2007). While this is still a significant number, it masks the relative importance of this group for nation-wide poverty reduction. Only 19 percent of rural households are engaged in cocoa production, and poor cocoa growing households only constitute 3.4 percent of all rural households (Figure 3).

There are two points that further explain the limited potential of cocoa to contribute to future poverty reduction. First, cocoa production is geographically concentrated and its contribution to poverty reduction is therefore not distributed evenly across the country. According to GLSS 5, about two-thirds of cocoa is produced in the forest zone, where the share of rural poor is below national average, followed by the Southern Savannah zone with about 30 percent (mainly Brong Ahafo region); the remainder is produced in the coastal zone (GSS 2007). In the North, where poverty is highest, natural conditions are not suitable for cocoa production (see maps A1 and A2). Second, the share of cocoa income in the poor's total agricultural income is only about 10 percent, while its importance increases for higher-income

quintiles. The richest rural households generate about 30 percent of their agricultural income from cocoa (Table 1).

Figure 2. Distribution of poor rural households versus poor rural cocoa households



Source: Authors' calculations using GLSS 5.
Note: Only rural cocoa-producing households are included in calculations.

Table 1. Sources of income of rural households (share of total agricultural income)

	1st quintile	2nd quintile	3rd quintile	4th quintile	5th quintile
Maize	9.1	9.1	9.9	9.2	9.5
Sorghum and millet	4.2	1.5	1.5	1.0	0.7
Root crops	27.3	34.1	24.5	17.1	13.1
Cocoa	**10.5**	**10.2**	**18.8**	**20.4**	**29.6**
Other cash crops	3.9	3.1	3.8	4.5	4.7
Fruits	3.6	4.8	7.1	10.2	9.6
Vegetables	9.0	10.6	9.0	15.6	10.5
Processed food	9.9	5.4	7.3	10.5	6.8
Other agricultural income	22.4	21.2	18.1	11.5	15.6

Source. Authors' calculations from GLSS 5.

III. ASSESSING THE ROLE OF COCOA IN GHANA'S FUTURE DEVELOPMENT

Model specification

To capture the growth linkages of the cocoa sector and its contribution to reaching MIC status in Ghana, we develop a dynamic computable general equilibrium (CGE) model.[3] This model explicitly captures cocoa production technology, cocoa's intermediate and export demand, and household incomes from cocoa production. The model includes cocoa production in the coast, forest, and southern savannah zone.[4] To capture the linkages and interactions of the cocoa sector with other sectors in detail, the CGE model also incorporates information on the demand and production structure of 58 other sectors of Ghana's economy.[5] Agriculture is disaggregated into 27 sub-sectors and industry is disaggregated across 22 sectors. Within industry, the model captures major backward linkages of the cocoa sector, including industrial inputs, such as fertilizer, and pesticides used as inputs. The model also includes industries that use cocoa as an input in production, such as cocoa processing and other food-processing sectors, such as bakery, chocolate products, etc. (forward linkages). In the base, 15 percent of Ghana's cocoa beans are processed domestically, while the remaining output is exported and generates income for the government, which receives a fixed share of export revenues via the export tax. The model also incorporates 10 service sectors, including cocoa marketing and trade provided by trade and transport services. Cocoa-producing households are represented by regionally disaggregated rural households that earn their income from factors of production employed in cocoa production, including immobile family labor, unskilled labor that is mobile, capital, and land. The contribution of cocoa and the other economic sectors to national GDP is calculated using a set of data, which includes national accounts provided by Ghana Statistical Services (GSS). Information on the cocoa sector comes from the Cocoa Board and MOFA.

The CGE model also includes a microsimulation module that allows for the endogenous estimation of growth impacts on households' poverty. These household

[3] Please find the mathematical model specification in the Annex.
[4] Broadly speaking, the coastal zone covers the Eastern and Volta regions; the forest zone includes Ashanti, Western, and Central regions; the southern savannah is Brong Ahafo and part of Volta.
[5] The SAM has been jointly constructed by Ghana Statistical Services (GSS) and the International Food Policy Research Institute (IFPRI) (Breisinger et al. 2007).

groups include both rural and urban households and are disaggregated across four regions, plus the Greater Accra region. Each of these households, which were included in the 2005–06 Ghana Living Standard Survey (GLSS5), is linked directly to its corresponding representative household in the CGE model. In this formulation, the CGE model's changes in representative households' consumption and prices are imposed on their corresponding households in the survey, where total consumption expenditures are recalculated. This new level of per capita expenditure for each survey household is compared to the official poverty line.

The role of cocoa in achieving MIC status

Reaching MIC status will require doubling per capita incomes from the current US$450 to US$1,000 by 2015. Because of the important role that cocoa has played throughout history, and in recent growth acceleration, we use the CGE to look at the role of cocoa in future growth. Given cocoa production targets, existing yield gaps, and land-area expansion potentials, we incorporate the sector into the overall growth path of Ghana to reach MIC status. Farm-level productivity growth is assumed to come from farmers' adoption of new production technology (e.g. improved planting material, pest management, soil fertility management, etc.).

Aggregate model results suggest that 7.6 percent GDP growth is required to reach MIC status by 2015 (Table 2). Under this scenario, agriculture grows at 6.9 percent, and growth in industry and services accelerates to 8.9 and 7.4 percent, respectively (Table 2). Agriculture will continue to play an important role in Ghana's economy and will remain the main contributor to overall growth on the way to MIC status, but industry will pay an increasingly important role. Along this MIC growth path, per capita GDP will reach about US$1,000 (Table 2).[6] Poverty will also greatly decline and reach levels of around 10 percent.

While growth in all sectors will have to accelerate, cocoa will have to continue to play an important role in reaching MIC status by supporting agricultural growth, earning foreign exchange to finance surging capital goods imports, and providing inputs required in food-processing sectors. Supporting this growth will require cocoa growth of 6.3 percent annually, slightly above average agricultural growth rates, but well below the 14.8 percent average annual growth rate achieved between 2001–2005.

[6] The model results of increased GDP and per capita GDP are measured in 2005 US$ and assume a currency appreciation of about 2 – 5 percent based on recent years' average.

Under the assumption that land for cocoa production is limited and world-market prices remain constant, total cocoa production reaches about 1.36 million tons by 2015. Yields increase to 0.65 tons per hectare, which is still well below existing yield potentials. This indicates further potentials for productivity increases, in which case no further expansion of land would be required.

Table 2. Model results: GDP growth and aggregate sector's contribution

	Initial value in 2005	Base-run scenario	MIC scenario
Part A. Annual growth rate of 2006–2015 (%)			
Total GDP	5.6	5.6	7.6
Agriculture	5.3	5.3	6.9
Industry	5.7	5.9	8.9
Services	5.6	5.7	7.4
Part B. Sector's contribution to GDP growth (%)			
Agriculture		38.8	35.5
Industry		29.4	34.7
Services		31.8	29.8
Part C. Sector share of GDP by 2015 (%)			
Agriculture	38.7	40.9	39.4
Industry	27.9	27.9	29.8
Services	33.4	31.2	30.9
Part D. Per capita income in current $USD by 2015 ($US)			
Total GDP	454	774	956
Agriculture	176	316	376
Industry	127	216	284
Services	152	242	295

Source: Authors' calculation based on CGE model results

Ghana's economic structure will change and cocoa's relative role will decline in the process. Because of even faster growth in other sectors, the share of cocoa in GDP will decline from 7.3 percent to 6.5 percent by 2015. Cocoa's share in agriculture will decline, but still account for a remarkable 16.5 percent of agricultural GDP. On the regional level, however, the share of agriculture will remain largely constant—or even slightly increase in the case of the forest zone.

Table 3. Model results: Cocoa's role in reaching MIC status

	Initial	MIC 2015
Production		
Output (MT)	739,861	1,361,206
Yield (MT/ha)	0.40	0.65
Land (ha)*	1,849,653	2,100,000
Cocoa and cocoa processing in GDP		
Annual average cocoa GDP growth		6.30
Total cocoa GDP (in billion cedis)	6,515	11,987
Share of cocoa in GDP	7.3	6.5
Share of cocoa in Ag GDP	18.9	16.5
Share of cocoa in regional Ag GDP		
Coast	5.4	5.6
Forest	32.2	34.7
South Savannah	23.9	23.8
Share of cocoa processing in manufacturing	4.4	4.3
Share of cocoa process. in agri-related manuf. GDP	7.1	6.7
Cocoa and cocoa-processing exports		
Annual average cocoa export growth		6.03
Share of total exports		
Cocoa	24.3	20.3
Cocoa processing	3.8	4.2
Share of sector exports		
Share of cocoa in agricultural exports	52.0	43.5
Share of cocoa process in manufacturing exports	24.8	19.0

Source: Authors' calculations, based on CGE model results
Note: *Assumed maximum of available land

Cocoa will remain the most important agricultural export sector, accounting for about 44 percent of agricultural exports by 2015 and contributing about 20 percent of foreign-exchange earnings. This high share is contrary to most other countries' experiences, in which periods of rapid growth have often been accompanied by a greater diversification of production and exports. In a sample of six countries that managed to double their incomes to reach MIC status within a decade, as Ghana plans to, only in Malaysia did the agricultural sector grow rapidly and remain dependent on a single dominant agricultural export (palm oil). So, while Ghana might follow the path of Malaysia on the way to MIC status, it certainly will have to further diversify its exports in the long run. Model results also suggest that, without additional investments in the cocoa processing sector, its share will remain well below countries such as Cote d'Ivoire.

IV. CONCLUSIONS

This paper has analyzed the role of cocoa in Ghana's recent growth and poverty reduction. It has also used a CGE model to evaluate the potential role of cocoa on the way to MIC status. Growth projections in the model are based on past growth trends, and synergizing sub-sector-specific growth accelerations produces a scenario in which Ghana can reach MIC status by 2015.

We find that reaching MIC status will require strong growth in all sectors, including traditional agricultural commodities like cocoa. To fully realize cocoa's growth potentials and to use the sector to support economy-wide growth acceleration, several challenges remain. Cocoa production will have to increase by about 60,000 tons annually over the next decade to help Ghana reach MIC status. Because of the scarcity of suitable land and an expected decrease in the amount of available family labor in the cocoa sector, this growth will have to be primarily driven by productivity increases. Yield growth has slowed during 2005–2006, however, and micro-evidence indicates that yield increases during 2002–2004 have been largely driven by additional family labor and favorable weather conditions. Additional efforts will therefore be necessary to accelerate sustainable productivity growth through intensification in the cocoa sector. Increased production through area expansion will have significant environmental costs.

The value addition to cocoa in Ghana through agro-processing is relatively low. Other cocoa-producing countries, such as Cote d'Ivoire, reach higher shares, and a recent increase in processed cocoa exports in Ghana might indicate future potentials. Developing agro-processing could also be an important step towards a more diversified economy. While Malaysia has demonstrated that it is possible to reach MIC status through strong agricultural growth and exports of a single agricultural commodity, a more diversified economic and export structure will be key for Ghana's future development beyond MIC status.

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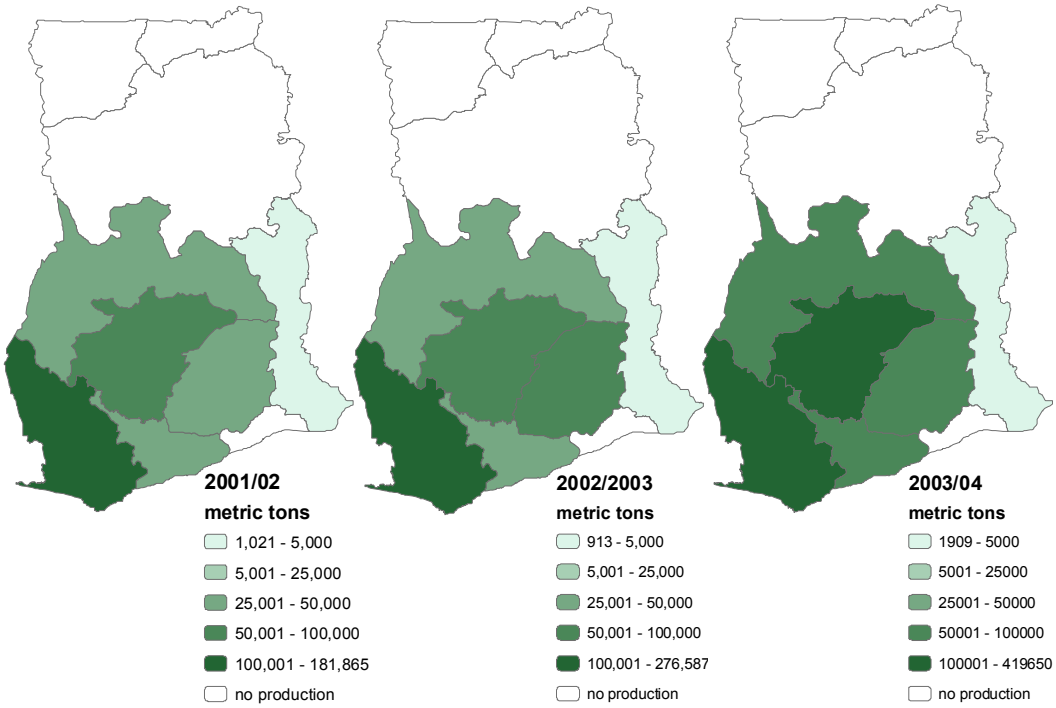
APPENDIX

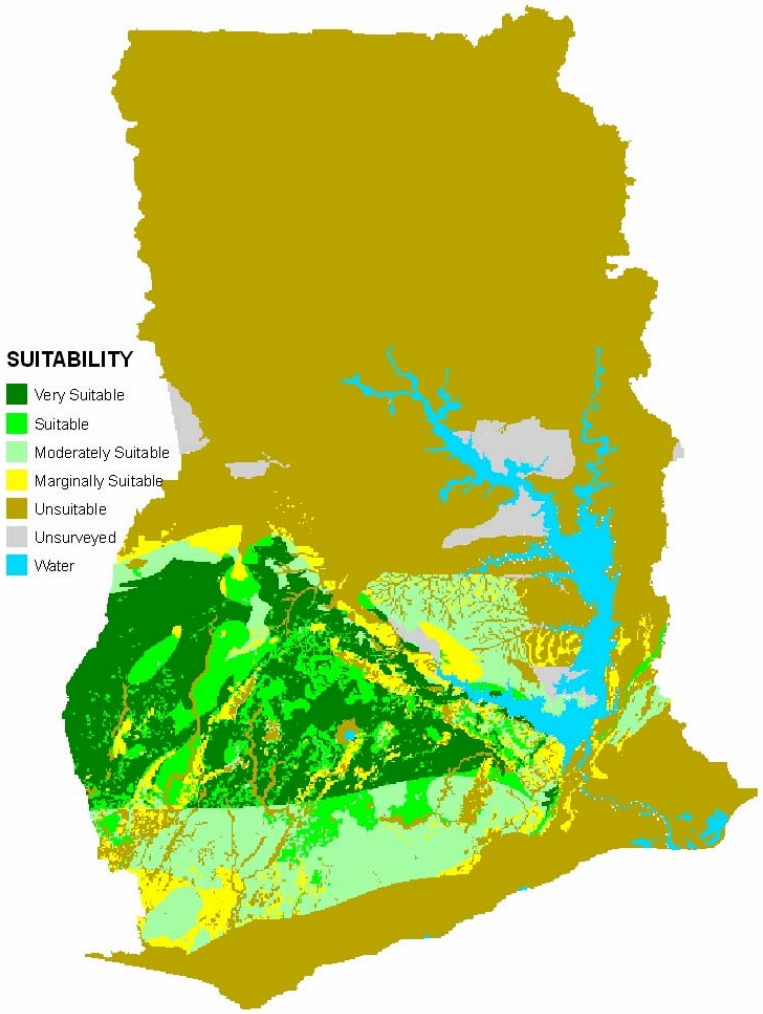
Appendix 1

Figure A1.1 Cocoa production in Ghana



Source: Chamberlin 2007

Figure A1.2 Suitability of cocoa production in Ghana



Source: Chamberlin 2007

Appendix 2

Table A1. Sectors and commodities in the computable general equilibrium model for Ghana

Agriculture	Industry	Services
Cereal crops	Mining	Private
Maize	Food processing	Trade services
Rice	Formal food processing	Export services
Sorghum and millet	Informal food processing	Transport services
Other cereals	Cocoa processing	Communication
Root crops	Dairy products	Banking and business
Cassava	Meat and fish processing	Real estate
Yams	Other manufacturing	Public and community
Cocoyams	Textiles	Community and other services
Other staple crops	Clothing	Public administration
Cowpea	Leather and footwear	Education
Soya beans	Wood products	Health
Groundnuts	Paper, publishing, and printing	
Fruit (domestic)	Crude and other oils	
Vegetables (domestic)	Petroleum	
Plantains	Diesel	
Other crops	Other fuels	
Export crops	Fertilizer	
Palm oil	Chemicals	
Other nuts	Metal products	
Fruit (export)	Machinery and equipment	
Vegetables (export)	Other industry	
Cocoa beans	Construction	
Industrial crops	Water	
Livestock	Electricity	
Chicken broiler		
Eggs and layers		
Beef		
Sheep and goat meat		
Other meats		
Forestry		
Fishery		

Table A2.1 Sets, parameters, and variables of the computable general equilibrium model

Symbol	Explanation	Symbol	Explanation
Sets			
$a \in A$	Activities	$c \in CEN(\subset C)$	Commodities not in *CE*
$a \in ALEO(\subset A)$	Activities with a Leontief function at the top of the technology nest	$c \in CM(\subset C)$	Aggregate imported commodities
$c \in C$	Commodities	$c \in CMN(\subset C)$	Commodities not in *CM*
$c \in CD(\subset C)$	Commodities with domestic sales of domestic output	$c \in CX(\subset C)$	Commodities with domestic production
$c \in CDN(\subset C)$	Commodities not in *CD*	$f \in F$	Factors
$c \in CE(\subset C)$	Exported commodities	$h \in H(\subset INSDNG)$	Households
Equation parameters			
cpi	Consumer price index	$mps01_i$	0–1 parameter with 1 for institutions with potentially flexed direct tax rates
$cwts_c$	Weight of commodity c in the CPI	pwe_c	Export price (foreign currency)
ica_{ca}	Quantity of c as intermediate input per unit of activity a	$shif_{if}$	Share for domestic institution *i* in income of factor *f*
$icd_{cc'}$	Quantity of commodity c as trade input per unit of *c´* produced and sold domestically	$shii_{ii'}$	Share of net income of i´ to *i* (*i´* ∈ *INSDNG´*; i ∈ *INSDNG*)
$ice_{cc'}$	Quantity of commodity c as trade input per exported unit of *c´*	ta_a	Tax rate for activity a
$icm_{cc'}$	Quantity of commodity c as trade input per imported unit of *c´*	$tins_i$	Exogenous direct tax rate for domestic institution i
$inta_a$	Quantity of aggregate intermediate input per activity unit	$tins01_i$	0–1 parameter with 1 for institutions with potentially flexed direct tax rates
iva_a	Quantity of aggregate intermediate input per activity unit	tm_c	Import tariff rate
mps_i	Base savings rate for domestic institution i	tq_c	Rate of sales tax

Table A2.1 Sets, parameters, and variables of the computable general equilibrium model (continued)

Symbol	Explanation	Symbol	Explanation
Equation parameters, continued			
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			
$fsav$	Foreign savings (FCU)	qg_c	Government consumption demand for commodity
mps_i	Marginal propensity to save for domestic nongovernment institution (exogenous variable)	$qinv_c$	Base-year quantity of private investment demand
pwm_c	Import price (foreign currency)	$trnsfr_{i\,f}$	Transfer from factor *f* to institution *i*
$qdst_c$	Quantity of stock change	$wfdist_{fa}$	Wage distortion factor for factor f in activity a
qfs_f	Quantity supplied of factor		
Endogenous variables			
AWF_{ft}^a	Average capital rental rate in time period *t*	$QINTA_a$	Quantity of aggregate intermediate input
$IADJ$	Investment adjustment factor	$QINT_{ca}$	Quantity of commodity *c* as intermediate input to activity *a*
EG	Government expenditures	$QINV_c$	Quantity of investment demand for commodity
EH_h	Consumption spending for household	QM_{cr}	Quantity of imports of commodity *c*
EXR	Exchange rate (LCU per unit of FCU)	PA_a	Activity price (unit gross revenue)
$GSAV$	Government savings	PD_c	Demand price for commodity produced and sold domestically
QF_{fa}	Quantity demanded of factor *f* from activity *a*	PE_{cr}	Supply price for commodity produced and sold domestically
QH_{ch}	Quantity consumed of commodity *c* by household *h*	$PINTA_a$	Export price (domestic currency)
QHA_{ach}	Quantity of household home consumption of commodity *c* from	PK_{ft}	Aggregate intermediate input price for activity *a*

	activity *a* for household *h*		
PM_{cr}	Unit price of capital in time period *t*	QX_c	Aggregated quantity of domestic output of commodity
PQ_c	Import price (domestic currency)	$QXAC_{ac}$	Quantity of output of commodity *c* from activity *a*
PVA_a	Composite commodity price	$TRII_{ii'}$	Transfers from institution *i′* to *i* (both in the set *INSDNG*)
PX_c	Value-added price (factor income per unit of activity)	WF_f	Average price of factor
$PXAC_{ac}$	Aggregate producer price for commodity	YF_f	Income of factor *f*
QA_a	Producer price of commodity *c* for activity *a*	YG	Government revenue
QD_c	Quantity (level) of activity	YI_i	Income of domestic nongovernment institution
QE_{cr}	Quantity sold domestically of domestic output	YIF_{if}	Income to domestic institution *i* from factor *f*
QQ_c	Quantity of goods supplied to domestic market (composite supply)	K^a_{fat}	Quantity of new capital by activity *a* for time period *t*
QVA_a	Quantity of (aggregate) value-added		

Table A2.2. Equations of the computable general equilibrium model

Production and price equations	
$QINT_{ca} = ica_{ca} \cdot QINTA_a$	(1)
$PINTA_a = \sum_{c \in C} PQ_c \cdot ica_{ca}$	(2)
$QVA_a = \alpha_a^{va} \cdot \left(\sum_{f \in F} \delta_{fa}^{va} \cdot \left(\alpha_{fa}^{vaf} \cdot QF_{fa} \right)^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}}$	(3)
$W_f \cdot \overline{WFDIST}_{fa} = PVA_a \cdot QVA_a \cdot \left(\sum_{f \in F'} \delta_{fa}^{va} \cdot \left(\alpha_{fa}^{vaf} \cdot QF_{fa} \right)^{-\rho_a^{va}} \right)^{-1} \cdot \delta_{fa}^{va} \cdot (\alpha_{fa}^{vaf})^{-\rho_a^{va}} \cdot \left(QF_{fa} \right)^{-\rho_a^{va}-1}$	(4)
$QVA_a = iva_a \cdot QA_a$	(5)
$QINTA_a = inta_a \cdot QA_a$	(6)
$PA_a \cdot (1 - ta_a) \cdot QA_a = PVA_a \cdot QVA_a + PINTA_a \cdot QINTA_a$	(7)
$QXAC_{ac} = \theta_{ac} \cdot QA_a$	(8)
$PA_a = \sum_{c \in C} PXAC_{ac} \cdot \theta_{ac}$	(9)
$QX_c = \alpha_c^{ac} \cdot \left(\sum_{a \in A} \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}} \right)^{-\frac{1}{\rho_c^{ac}-1}}$	(10)
$PXAC_{ac} = PX_c \cdot QX_c \left(\sum_{a \in A'} \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}} \right)^{-1} \cdot \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}-1}$	(11)
$PE_{cr} = pwe_{cr} \cdot EXR - \sum_{c' \in CT} PQ_c \cdot ice_{c'c}$	(12)
$QX_c = \alpha_c^t \cdot \left(\sum_r \delta_{cr}^t \cdot QE_{cr}^{\rho_c^t} + (1 - \sum_r \delta_{cr}^t) \cdot QD_c^{\rho_c^t} \right)^{\frac{1}{\rho_c^t}}$	(13)
$\frac{QE_{cr}}{QD_c} = \left(\frac{PE_{cr}}{PD_c} \cdot \frac{1 - \sum_r \delta_{cr}^t}{\delta_c^t} \right)^{\frac{1}{\rho_c^t - 1}}$	(14)
$QX_c = QD_c + \sum_r QE_{cr}$	(15)
$PX_c \cdot QX_c = PD_c \cdot QD_c + \sum_r PE_{cr} \cdot QE_{cr}$	(16)
$PM_{cr} = pwm_{cr} \cdot (1 + tm_{cr}) \cdot EXR + \sum_{c' \in CT} PQ_{c'} \cdot icm_{c'c}$	(17)

Table A2.2 Equations of the computable general equilibrium model (continued)

$$QQ_c = \alpha_c^q \cdot \left(\sum_r \delta_{cr}^q \cdot QM_{cr}^{-\rho_c^q} + (1 - \sum_r \delta_{cr}^q) \cdot QD_c^{-\rho_c^q} \right)^{-\frac{1}{\rho_c^q}} \quad (18)$$

$$\frac{QM_{cr}}{QD_c} = \left(\frac{PD_c}{PM_c} \cdot \frac{\delta_c^q}{1 - \sum_r \delta_{cr}^q} \right)^{\frac{1}{1+\rho_c^q}} \quad (19)$$

$$QQ_c = QD_c + \sum_r QM_{cr} \quad (20)$$

$$PQ_c \cdot (1 - tq_c) \cdot QQ_c = PD_c \cdot QD_c + \sum_r PM_{cr} \cdot QM_{cr} \quad (21)$$

$$cpi = \sum_{c \in C} PQ_c \cdot cwts_c \quad (22)$$

Institutional incomes and domestic demand equations

$$YF_f = \sum_{a \in A} WF_f \cdot wfdist_{fa} \cdot QF_{fa} \quad (23)$$

$$YIF_{if} = shif_{if} \cdot YF_f \quad (24)$$

$$YI_i = \sum_{f \in F} YIF_{if} + \sum_{i' \in INSDNG'} TRII_{ii'} + trnsfr_{igov} \cdot cpi + trnsfr_{irow} \cdot EXR \quad (25)$$

$$TRII_{ii'} = shii_{ii'} \cdot (1 - mps_{i'}) \cdot (1 - tins_{i'}) \cdot YI_{i'} \quad (26)$$

$$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{ih} \right) \cdot (1 - mps_h) \cdot (1 - tins_h) \cdot YI_h \quad (27)$$

$$PQ_c \cdot QH_{ch} = PQ_c \cdot \gamma_{ch}^m + \beta_{ch}^m \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma_{c'h}^m \right) \quad (28)$$

$$QINV_c = IADJ \cdot qinv_c \quad (29)$$

$$EG = \sum_{c \in C} PQ_c \cdot qg_c + \sum_{i \in INSDNG} trnsfr_{igov} \cdot cpi \quad (30)$$

$$YG = \sum_{i \in INSDNG} tins_i \cdot YI_i + \sum_{c \in CMNR} tm_c \cdot pwm_c \cdot QM_c \cdot EXR + \sum_{c \in C} tq_c \cdot PQ_c \cdot QQ_c + \sum_{f \in F} YF_{govf} + trnsfr_{govrow} \cdot EXR \quad (31)$$

System constraints and macroeconomic closures

$$QQ_c = \sum_{a \in A} QINT_{ca} + \sum_{h \in H} QH_{ch} + qg_c + QINV_c + qdst_c \quad (32)$$

$$\sum_{a \in A} QF_{fa} = QFS_f \quad (33)$$

$$YG = EG + GSAV \quad (34)$$

Table A2.2 Equations of the computable general equilibrium model (continued)

$$\sum_{r\ c\in CMNR} pwm_{cr}\cdot QM_{cr} = \sum_{r\ c\in CENR} pwe_{cr}\cdot QE_{cr} + \sum_{i\in INSD} trnsfr_{i\,row} + fsav \tag{35}$$

$$\sum_{i\in INSDNG} mps_i\cdot\left(1-\overline{tins}_i\right)\cdot YI_i + GSAV + EXR\cdot fsav = \sum_{c\in C} PQ_c\cdot QINV_c + \sum_{c\in C} PQ_c\cdot qdst_c \tag{36}$$

Factor accumulation and allocation equations (applies to capital only)

$$AWF^a_{f\,t} = \sum_a\left[\left(\frac{QF_{f\,a\,t}}{\sum_{a'} QF_{f\,a'\,t}}\right)\cdot WF_{f\,t}\cdot wfdist_{f\,a\,t}\right] \tag{37}$$

$$\eta^a_{f\,a\,t} = \left(\frac{QF_{f\,a\,t}}{\sum_{a'} QF_{f\,a'\,t}}\right)\cdot\left(\beta^a\cdot\left(\frac{WF_{f,t}\cdot wfdist_{f\,a\,t}}{AWF^a_{f\,t}}-1\right)+1\right) \tag{38}$$

$$\Delta K^a_{f\,a\,t} = \eta^a_{f\,a\,t}\cdot\left(\frac{\sum_c PQ_{c\,t}\cdot qinv_{c\,t}}{PK_{f\,t}}\right) \tag{39}$$

$$PK_{f\,t} = \sum_c PQ_{c\,t}\cdot\frac{qinv_{c\,t}}{\sum_{c'} qinv_{c'\,t}} \tag{40}$$

$$QF_{f\,a\,t+1} = QF_{f\,a\,t}\cdot\left(1+\frac{\Delta K^a_{f\,a\,t}}{QF_{f\,a\,t}}-\upsilon_f\right) \tag{41}$$

$$QFS_{f\,t+1} = QFS_{f\,t}\cdot\left(1+\frac{\sum_a K_{f\,a\,t}}{QFS_{f\,t}}-\upsilon_f\right) \tag{42}$$