

## Potential Regional Trade Implications of Adopting Bt Cowpea in West and Central Africa

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This paper used a spatial and temporal price equilibrium model to assess the potential impacts of farmers in West and Central Africa adopting *Bacillus thuringiensis* (Bt) cowpea (*Vigna unguiculata* (L.) Walp). The results showed that regional cowpea prices would decrease, leading to increased regional demand and increased supply only in adopting countries. Total cowpea traded and regional welfare would increase, but producers in nonadopting countries would lose. The results thus emphasize regional adoption of any Bt cowpea and suggest that policy makers devise ways of ensuring equitable distribution of benefits.

**Key words:** ad valorem tariff, Africa, biotechnology, interest rates, *Maruca testulalis*, mixed complementary programming, spatial and temporal price equilibrium.

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### Introduction

Cowpea (*Vigna unguiculata* (L.) Walp) is the most economically important indigenous African grain legume and a major item in regional trade within West and Central Africa, where about 80% of the world cowpea trade takes place (Langyintuo et al., 2003). Officially, an estimated 300,000 metric tons of cowpea is traded each year within the Nigerian Cowpea Grainshed (NCG; Figure 1), but the actual commerce is probably somewhat larger (Langyintuo, Lowenberg-DeBoer, & Arndt, 2005). For millions of farmers in the semiarid areas of West and Central Africa, cowpea is an important cash crop, as well as part of their subsistence consumption.

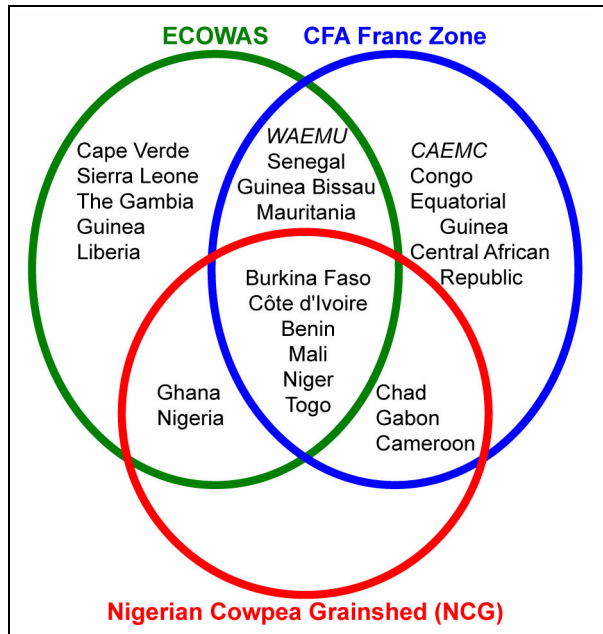
Cowpea yields in West and Central Africa are low. The cowpea pod borer (*Maruca testulalis*) is a key problem (Murdock et al., 1997). Insecticides provide effective control of *Maruca* but are often not available to poor farmers, or, if available, they are misused by illiterate growers. There is no natural source of genetic resistance to *Maruca*, but there is an effort underway to introduce *Bacillus thuringiensis* (Bt) genes (Machuka, 2002; Sithole-Niang et al., 2001). The objective of this study was to estimate the potential impacts of Bt cowpea adoption on regional cowpea trade and welfare of cowpea producers and consumers. Would the substantial production increases with Bt cowpea lead to sharply lower market prices and a loss of producer welfare?

To answer this question, a spatial and temporal price equilibrium (SPE) model was formulated for the region. Cowpea, unlike industrial raw material crops, is traded almost exclusively within Africa and thus affords the opportunity to make the analysis without worrying about external trade policy implications. The results of this study have broad implications for researchers and

policy makers interested or involved in cowpea technology development and diffusion as well as African regional trade issues.

Annual cowpea production in West and Central Africa in the last decades has averaged 2.6 million tons on 7.8 million ha, accounting for 69% of the world's production (Langyintuo et al., 2003). In addition to field pests, cowpea yields are reduced by use of low-yielding traditional varieties, poor soil fertility, unfavorable weather, and inefficient crop management practices (Blade, Shetty, Terao, & Singh, 1997; Diehl & Sipkins, 1985; Montimore, Singh, Harris, & Blade, 1997; Sawadogo, Nagy, & Ohm, 1985; Semi-Arid Food Grain Research and Development, 1998; Singh, Chamblis, & Sharma, 1997). *Maruca* can reduce cowpea pod yields by 17–53% (Liao & Lin, 2000). Insecticides are often not locally available or too expensive for smallholder farmers. Health problems related to misuse of insecticides (Ajayi & Waibel, 2003; Drafor, 2003; Maumbe & Swinton, 2003) are other reasons for considering a genetic solution to the pod borer problem.

In contrast to much of eastern and southern Africa, there is political support for adoption of genetically modified (GM) crops in West and Central Africa. Nigeria has developed biosafety regulations and procedures that would allow testing of GM crops (Africast, 2001; European NGO Network on Genetic Engineering, 2002; Federal Ministry of Agriculture and Natural Resources, 1994). The presidents of Niger, Mali, Burkina Faso, and Ghana have given their approval to the use of biotechnology to improve food security (United States Department of Agriculture, 2004). The establishment of the African Agricultural Technology Foundation (AATF), which aims at promoting both classical plant breeding



**Figure 1. Membership of ECOWAS, CFA Franc Zone, and Nigerian Cowpea Grainshed.**

*Note.* Data from Langyintuo et al. (2005). Ghana, Burkina Faso, Niger, and Cameroon belong to the Bean/Cowpea CRSP countries.

and novel GM approaches to increase incomes and food security for the rural poor in sub-Saharan Africa, would boost African farmers' access to biotechnology (Chege, 2004). AATF has designated cowpea as one of three crops targeted for improvement using biotechnology (United States Agency for International Development, 2003).

The Economic Community of West African States (ECOWAS), to which many of the countries within the NCG belong (Figure 1), has eliminated all tariffs on agricultural imports, but nontariff barriers (such as inefficient transportation services, different currencies, numerous road checkpoints, and unofficial taxes) have tended to increase transaction costs that impede trade (Gambari, 1991; Henink & Owusu, 1998; Knowles, 1990; Obadan, 1984). To move towards regional integration to enhance trade through lowering transaction costs, ECOWAS is determined to establish a free trade zone alongside a West African Monetary Zone (WAMZ) by December 2009, whereby member countries would use a common currency and monetary policy managed by a West Africa Central Bank (ECOWAS, 2001; Masson & Pattillo, 2001). In their analysis of the potential impacts of the proposed WAMZ on grain trade in the region, Langyintuo et al. (2005) showed that if the

WAMZ results in reduced real interest rates and trade barriers within ECOWAS, trade volume would increase.

### Modeling Regional Trade Patterns Under Differential Interest Rates and Ad Valorem Tariffs

Formulating the SPE model—pioneered by Samuelson (1952) and subsequently advanced by Takayama and Judge (1964, 1971)—in the presence of differential interest rates or ad valorem tariffs poses some methodological challenges. In principle, an SPE model assumes that each possible pair of regions engaged in trade is separated by a transportation cost per physical unit independent of volume, and there are no legal restrictions to limit the actions of the profit-seeking traders in each region. Additionally, the functions that relate local production and use to local price are known. Consequently, the magnitude of exports or imports at each local price is also known (Harker, 1986; Takayama & Judge, 1971). Given these assumptions, a simple SPE model can be expressed as an optimization problem and solved for (a) the price in each region, (b) the quantity of exports or imports for each region, and (c) the volume and direction of trade between each possible pair of regions (See for example Labys & Yang, 1997; Minot & Goletti, 1998; Peeters, 1990).

Incorporating a specific tariff or constant discount rate in the static SPE model does not violate the integrability of the model, but an ad valorem tariff or differential interest rate does, preventing the SPE being formulated as a single optimization problem. To overcome this problem, the model has to be reformulated in a mixed complementary programming (MCP) framework, which consists of a set of simultaneous (linear or nonlinear) equations that are a mix of strict equalities and inequalities with each inequality linked to a bounded variable in a complementary slackness condition (Rutherford, 1995). The Kuhn-Tucker optimality conditions define an MCP with the necessary conditions for a local optimum for economic linear and nonlinear optimality problems.

In this study, the MCP formulation derived by Langyintuo (2003) was used, because countries within the NCG exhibited large differences in interest (or discount) rates (related to the stability of their economies) and the nontariff barriers between them were best expressed in terms of their ad valorem tariffs equivalents. A detailed presentation of the model is given by Langyintuo (2003) and Langyintuo et al. (2005).

After verifying that the base model sufficiently replicated the base year price, supply, and demand figures, as well as trade flows, the model was used in analyzing three counterfactual policy scenarios and compared with the base case results. Scenario 1 assumes that Bt cowpea is adopted only in Nigeria. Because any Bt cowpea varieties would have to be multiplied and distributed to farmers, it is assumed that initially only 10% of the area is planted to Bt cowpea and subsequently increased to 100%. Refuge requirements usually limit the proportion of area planted to Bt crops to 50–80% of area planted, so the 100% scenario is included mainly as a theoretical limit.<sup>1</sup> In the context of political support for genetically modified crops in West and Central Africa, it is assumed that there are no barriers to trade for Bt cowpea within the region. Although there is some informal evidence that Maruca pressure varies from place to place, this analysis assumes uniform Maruca infestation and consequently uniform yield benefits from Maruca resistance. The uniformity assumption is used because the patterns of Maruca infestation are not yet well documented.

Scenario 2 assumes that Bt cowpea is adopted only in countries with full-fledged participation in the Bean/Cowpea Collaborative Research Support Program (CRSP), which has broad-based interdisciplinary programs in Burkina Faso, Cameroon, Ghana, and Niger (but only marketing research in Nigeria) and works closely with AATF. It is plausible that farmers in countries with full-fledged Bean/Cowpea CRSP programs will benefit from Bt cowpea technology earlier than their counterparts in the other countries. In Scenario 2 it is assumed that Bt cowpea is used on limited cropped areas, but enough to result in a 10% increase in aggregate yields. Finally, Scenario 3 assumed that Bt cowpea is adopted in each cowpea-producing country in the NCG on limited cropped areas but enough to result in a 10% increase in aggregate average yields.

## Data Sources

Production and prices data on cowpea were obtained from the statistical services departments of the respective countries. Supply prices were generally lower than demand prices; corresponding prices in surplus-produce-

ing countries were lower than those in deficit ones. Whereas supply and demand elasticities were obtained from the literature, benchmark demand data were estimated from per-capita consumption and population. For import and export data required for model validation, data from country pairs were compared and the highest of the two taken. Distances between major wholesale markets in national capitals were computed from digital maps; transportation losses were assumed to be 1% per each shipment. Following Golob, Stringfellow, & Asante (1996), a 15% per-quarter storage loss factor was assumed.

Deciding on the appropriate discount factor to use was a challenge, because traders rely on the informal rather than the formal financial sector for credit despite the relatively higher interest rates in the former compared with the latter (Basu, 1997; Bose, 1998; Evers & Mehmet, 1994; Lowenberg-DeBoer, Abdoulaye, & Kabore, 1994; Warning & Sadoulet, 1998) for reasons such as traders simply not being considered creditworthy (Bose, 1998) and rationing of credit to traders (Chakrabarty & Chaudhuri, 2001; Kochar, 1997). Even when traders obtain credit from formal financial institutions, the effective interest rates are often as high as informal sector rates because of delays in disbursement or bribes/fees that have to be paid to ensure timely delivery (Chaudhuri & Gupta, 1996). To avoid any complications, commercial bank interest rates were used and the model results found to be stable following sensitivity analyses.

The cost of transporting commodities from source to destination market is the upper limit on the price differentials between the markets unless there are barriers to trade, which reduce the flow of goods and thereby increase the supply in the surplus region (reducing prices) while decreasing supply in the deficit region (increasing prices). The net effect is to increase the price differential between the two regions. Information on the degree of restrictions on nontraditional international trade barriers are difficult to obtain. If tolls and other fees are collected by local authorities, it is more difficult to estimate the size of those costs. Similarly, data on the costs associated with delays due to roadblocks and bureaucratic obstacles are not easy to collect. Following Minot and Goletti (1998), the implicit costs related to restrictions on trade were estimated by comparing the observed price differentials between source and destination markets with the actual cost of transportation. The difference between the two measured in percent of demand price is an aggregate measure of the costs associated with restrictions on trade. This percentage was

1. *Refuge requirements for Bt crops are used to help reduce the development of pest resistance. Nonresistant insects continue to reproduce in the refuges and hence dilute the selection pressure. Studies focused on setting refuge requirements for Bt cowpea are underway, but percentages have not yet been established.*

**Table 1. Base model results on supply, demand, and prices using linear functions.**

	Supply		Quarterly demand		Demand price	
	(1000 t)	% deviation from benchmark	(1000 t)	% deviation from benchmark	(US\$/t)	% deviation from benchmark
<b>CRSP countries</b>						
<b>Burkina Faso</b>	135.27	10.91	6.48	-15.84	527	31.91
<b>Cameroon</b>	51.45	0.16	9.33	1.64	404	-7.43
<b>Ghana</b>	77.53	10.00	41.00	-3.00	565	7.33
<b>Niger</b>	681.44	5.66	8.45	-8.03	533	40.63
<b>Non-CRSP countries</b>						
<b>Benin</b>	78.46	3.36	13.34	-3.05	534	7.48
<b>Chad</b>	18.29	1.42	2.81	-0.11	429	-0.31
<b>Côte d'Ivoire</b>	18.76	5.49	20.79	-6.14	602	16.89
<b>Gabon</b>	—	—	0.53	16.78	458	-47.96
<b>Mali</b>	113.09	2.12	16.06	-4.08	529	16.10
<b>Nigeria</b>	2,346.34	10.62	654.99	-3.88	591	14.60
<b>Togo</b>	33.43	4.47	10.15	-2.37	555	6.90
<b>Total/average</b>	3,554.06	8.90	783.93	-3.94	—	—

treated as an ad valorem tariff equivalent. Data on official specific tariffs, such as value added taxes, were obtained directly from country statistics.

## Results and Discussions

The supply analysis assumed that area devoted to cowpea in each country remained roughly stable. Changes in crop rotations, intercropping strategies, and other broad modifications of the farming system were considered beyond this analysis of trade effects. The results simulated cowpea trade in 1999/2000 marketing year in terms of supply, demand, imports, and exports of cowpea given existing policies.

### Base Model Results

Using linear demand and supply functions, the base scenario predicted 3.6 million t of cowpea produced, about 9% higher than the benchmark figure, while demand was about 4% less (Table 1). The largest percentage deviations between predicted and observed supply were in Burkina Faso (11%), Ghana (10%), and Nigeria (11%), while the lowest were in Cameroon (0.16%) and Chad (1.42%). The direction and volume of cowpea flow presented in Table 2 were consistent with reality. An estimated 540,000 t of cowpea were shipped to Nigeria (75.8%), Ghana (12.7%), Côte d'Ivoire (9.6%), Togo (1.3%), and Gabon (0.6%). Ninety-five percent of Nigeria's imports originated from Niger, which accounted for 98% of the latter's marketable surplus.

Because of the differential interest rates and ad valorem tariffs, welfare measures could not be estimated directly from the MCP formulation. Rather, estimates were based on the Judge and Takayama measure, which could have prevailed if an iterative nonlinear programming optimization scheme had been employed. In the base scenario, cowpea trade generated a net social welfare (or total surplus) of US\$6.3 billion, of which 60% went to producers and 40% to consumers (Table 3). In terms of regional distribution, Nigeria accounted for 63%, Niger 20%, and the other countries the remaining 17%. Whereas in Nigeria benefits were shared almost equally between producers and consumers, in Niger and Mali over 90% of the total surplus went to producers. The loss in welfare to producers and consumers through nontariff barriers was equivalent to about US\$12 million, or 0.2% of net social welfare. Total per-capita surplus ranged from US\$2 in Gabon to US\$117 in Niger. Nigeria, with the largest proportion of total surplus, is third after Mali in per-capita terms. Similarly, in terms of producer surplus per person in the farming population, Niger is first with US\$208 followed by Mali with US\$83 and third by Nigeria and Benin with US\$26 each. Côte d'Ivoire is the least with only US\$2.4.

### The Potential Impacts of Bt Cowpea Being Adopted in Only Nigeria

In Scenario 1, it was assumed that yields from Bt cowpea were 100% more than the current farm level yield of 494 kg/ha (Singh et al., 1997). Because cowpea growers

Table 2. Optimal interregional cowpea shipment in the base case (1000 t).

Exporter	Importer	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun
<b>CRSP exporting countries</b>					
Burkina Faso	Côte d'Ivoire	—	—	4.27	13.85
Burkina Faso	Ghana	—	6.17	33.37	19.15
Cameroon	Nigeria	4.90	—	—	—
Cameroon	Gabon	0.54	1.73	—	—
<b>Non-CRSP exporting countries</b>					
Benin	Nigeria	—	—	—	7.63
Benin	Togo	—	—	—	6.75
Mali	Côte d'Ivoire	2.06	19.05	12.41	—
Niger	Ghana	—	—	—	9.16
Niger	Nigeria	—	—	—	385.83
Chad	Nigeria	8.14	—	—	—

Table 3. Surplus measures in the base case scenario.

	Consumer surplus (million US\$)	Producer surplus (million US\$)	Total surplus (million US\$)	Producer surplus per farmer (US\$)	Total per-capita surplus (US\$)
<b>CRSP countries</b>					
Burkina Faso	4.80	136.69	111.61	10.11	2.67
Cameroon	35.49	113.65	142.86	25.26	2.06
Ghana	86.80	63.35	144.56	4.32	7.69
Niger	23.57	1,403.99	1,229.38	208.93	117.08
<b>Non-CRSP countries</b>					
Benin	19.95	101.36	106.14	25.96	17.40
Chad	2.42	27.66	29.39	4.26	7.59
Côte d'Ivoire	39.31	32.19	70.24	2.41	4.53
Gabon	2.73	—	2.47	—	19.05
Mali	40.74	376.31	400.27	82.56	37.76
Nigeria	2,086.89	2,217.02	3,980.02	25.56	32.12
Togo	22.21	34.05	52.36	8.92	11.38
<b>Total</b>	<b>2,364.91</b>	<b>4,506.27</b>	<b>6,269.31</b>	<b>27.94</b>	<b>—</b>

Note. Tariffs and tariff-equivalents of nontariff barriers. — = no value.

in the main production areas are well linked to traditional marketing channels (Langyintuo et al., 2003), it is highly likely that any increase in production in those regions would lead to increased sales. As farmers increased the area under Bt cowpea in Nigeria, regional prices decreased from 8% when 10% of the area was under Bt cowpea to 62% with 100% area under Bt cowpea (Table 4). At 80% area under cowpea (a typical refuge requirement for cowpea), regional prices are reduced by about 48%. This resulted in a region-wide increase in consumer demand. Because consumers in Nigeria increased their demand corresponding to the lower prices, Nigeria only began to export cowpea when at least 80% of the cowpea area was under Bt cowpea. At 85% of area under Bt cowpea, Nigeria exports an

estimated 26t of cowpea to Cameroon. This increases to about 1,000 t, 1,800 t, and 2,300 t with 90%, 95%, and 100% area under Bt cowpea, respectively. The increase in Nigeria's domestic supply forced Niger to redirect part of its exports meant for Nigeria to Benin, Ghana, and Togo, while Chad and Cameroon no longer exported to Nigeria. These changes resulted in the depression of regional prices to the benefit of consumers. Regional trade volume, however, decreased in part because Nigeria, the largest importer of cowpea (Langyintuo et al., 2003), substituted imported cowpeas with domestic production and in part because countries increased their domestic demand because of relatively lower domestic prices.

**Table 4. Relative changes in prices, demands and supply given a 10% increase in cowpea yields in selected countries in West and Central Africa (%).**

	10% yield increase in only Bean/Cowpea CRSP countries			10% yield increase in all NCG <sup>a</sup> countries		
	Price	Demand	Supply	Price	Demand	Supply
<b>Bean/Cowpea CRSP country</b>						
<b>Burkina Faso</b>	-2.97	22.76	6.62	-9.90	76.06	4.80
<b>Cameroon</b>	-3.14	3.64	8.80	-10.50	12.16	8.12
<b>Ghana</b>	-2.83	7.61	5.57	-9.44	25.42	3.29
<b>Niger</b>	-3.00	5.77	8.32	-10.01	19.28	7.41
<b>Non-Bean/Cowpea CRSP country</b>						
<b>Benin</b>	-2.97	10.44	-0.62	-9.77	34.39	5.91
<b>Chad</b>	-3.13	17.20	-0.45	-10.46	57.47	7.08
<b>Côte d'Ivoire</b>	-2.73	8.54	-0.47	-9.11	28.54	6.67
<b>Gabon</b>	-2.96	2.83	—	-9.90	9.46	—
<b>Mali</b>	-2.94	6.25	-0.24	-9.81	20.90	8.42
<b>Nigeria</b>	-2.84	5.27	-0.89	-9.48	17.60	3.89
<b>Togo</b>	-2.89	7.32	-0.79	-9.62	24.33	4.65
<b>Weighted average<sup>b</sup></b>	-2.85	5.73	1.62	-9.51	19.19	4.89

Note. — = no value.

<sup>a</sup> Gabon does not produce cowpeas.

<sup>b</sup> The weight was the proportion of cowpea demanded or supplied by country.

Producers in Nigeria benefited from the policy, in contrast to all other cowpea producers in the region, who suffered losses in welfare, mainly because the Nigerian producers sold more cowpeas than their counterparts who sold less at the same price. Within Nigeria, however, the change in consumer welfare was greater than the change in producer welfare at all levels of change in area under Bt cowpea (Figure 2). Figure 3 shows that with less than 20% of the area under Bt cowpea, consumer welfare gain was less than producer welfare gain in value terms. Beyond 20%, however, consumer welfare gain was greater than producer welfare gain and continued to increase at a linear rate, while the former increased at a decreasing rate.

#### **Potential Impacts of Bt Cowpea Being Adopted in Only the Bean/Cowpea CRSP Countries Within the NCG**

The simulation results showed that increasing cowpea supply by 10% in Burkina Faso, Cameroon, Ghana, and Niger (Scenario 2) led to a decrease in cowpea prices in all NCG countries (Table 4). Net exporting countries experienced the largest decline in domestic prices compared with net importing countries. The decline in domestic prices held down supply in all countries except in the target countries, which had relative yield advantage compared with the rest. In response to the supply

changes, stocks increased in the Bean/Cowpea CRSP countries, but decreased in non-Bean/Cowpea CRSP countries, due to decreased output. As expected, demand increased with a relatively larger percentage increase in countries with the largest decrease in domestic prices. The proportionate increase in demand in Benin, Burkina Faso, and Chad were more than twice the proportionate changes in supply, mainly because traders reduced exports in response to the lower regional export prices.

Significant changes in the direction and volume of cowpea trade relative to the base case occurred as a result of the policy. For example, Benin lost its market share in Nigeria to Niger but increased its shipment to Togo by more than 89% (6,500 t), which was eventually transshipped to Ghana. As Niger increased its shipment to Nigeria by 11%, it reduced its exports to Ghana by as much as 99%, which were captured by Burkina Faso and Benin. Chad cut back on its exports to Nigeria by 24%. In contrast, Cameroon increased its exports to Nigeria from 3,000 t to 9,000 t. Total trade volume increased by 9%. Net social welfare increased by 3%, or US\$182 million, but producers in all non-CRSP exporting countries suffered losses in welfare, because they sold less cowpea at relatively lower prices, unlike those in the countries affected by the policy, who sold more at similar prices. Nevertheless, all countries experienced

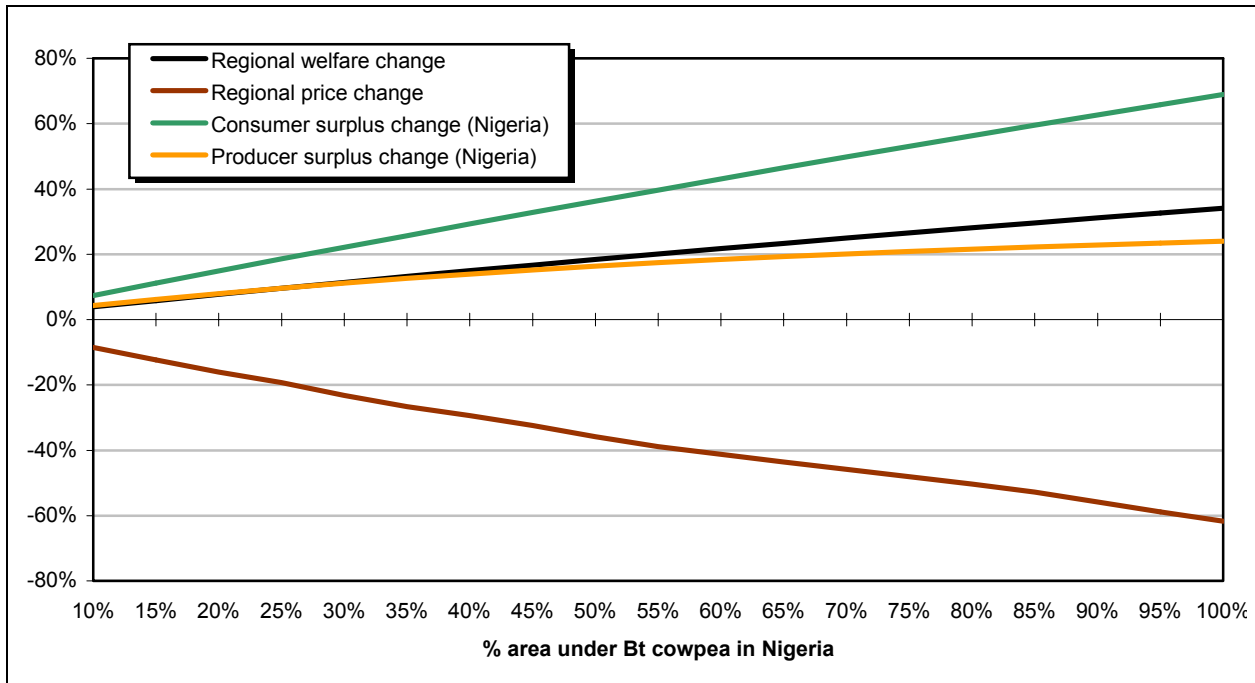


Figure 2. Simulation results showing percentage changes in parameters given changes in area under Bt cowpea in Nigeria.

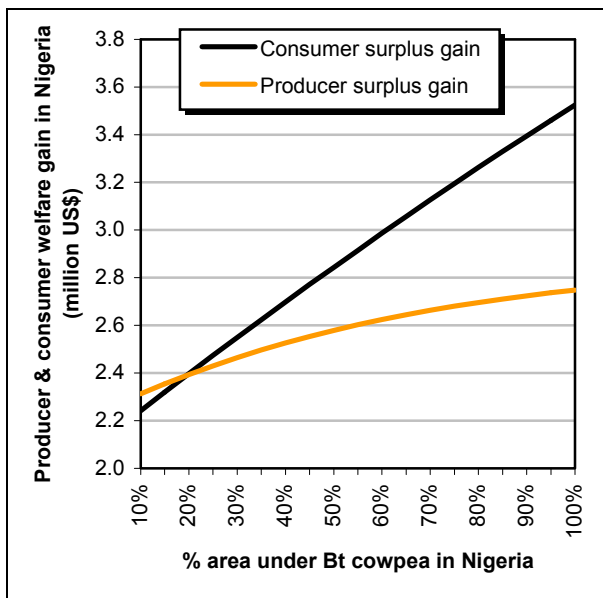


Figure 3. Simulation results of changes in producer and consumer welfare gains within Nigeria given changes in area under Bt cowpea in Nigeria alone.

improvement in total welfare, except Chad, where the loss in producer welfare outweighed the gain in consumer welfare so much so that total welfare decreased by 0.5%.

### Potential Impacts of Bt Cowpea Adopted in All Countries Within the NCG

When a 10% yield shock affected all countries in the NCG (Scenario 3), regional cowpea prices reduced more than in the case where only a selected countries were affected by the policy (Table 4). Nevertheless, total cowpeas traded increased from 536,000 t in the base case scenario to 581,000 t, or 8.5%. Although Nigeria increased its imports by 28,000 t over the base case, it was still 11,000 t less than when only CRSP countries experienced the supply shock. Cameroon increased its shipment to Nigeria but no longer shipped to Chad. Benin substantially increased its shipment to Togo, part of which was transshipped to Ghana. Ghana exported an estimated 1,600 t to Côte d'Ivoire between July and September, when neither Mali nor Burkina Faso exported any cowpeas to that country.

The total cowpea volume traded under this scenario was less than the scenario where only Bean/Cowpea CRSP countries benefited from the technology because of relatively larger proportionate decrease in regional prices discouraging grain shipment. Nevertheless, total regional welfare increased by over 8% or US\$485 million—more than twice the gain with a yield increase in only CRSP countries. All producers and consumers benefited from the policy, but producers benefited less than

consumers, because the latter purchased more cowpea at relatively cheaper prices.

### Concluding Remarks and Policy Implications

Cowpea (*Vigna unguiculata* (L.) Walp), the most economically important indigenous African grain legume, is an important item in regional trade within West and Central Africa. The growth and development of the cowpea industry, however, is hampered by field pests, especially pod borers (*Maruca testulalis*) and the storage weevil *Maruca*. Genetic transformation with *Bacillus thuringiensis* (Bt) genes offers an economically and ecologically sustainable way to combat pod borers, for which there are no natural sources of resistance. Using a spatial price equilibrium model, this study examined the potential impacts of farmers in Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Gabon, Ghana, Mali, Niger, Nigeria, and Togo within the Nigerian Cowpea Grainshed (NCG) adopting Bt cowpea on cowpea price, direction and volume of cowpea trade, and regional social welfare. This study provides an ex ante assessment of trade impacts that will help guide policy and research investment. The ex post trade impacts can only be tracked if and when Bt cowpea is introduced in West Africa.

The simulation of a Bt cowpea adoption in only Nigeria—the leading producer of cowpea and advocate for biotechnology in West and Central Africa—shows potential trade-distorting effects of uneven technology diffusion. With the increase in Nigerian production, cowpea imports from Niger to Nigeria were reduced, while Cameroon and Chad were shut out of the Nigerian market altogether. Niger drastically increased cowpea exports to Ghana and added Togo and Benin to its export markets. Nigeria could potentially be a net exporter of cowpea when over 80% of its cowpea area is planted to the Bt varieties, which appears unlikely because of refuge requirements that typically limit Bt crops to less than 80% of area planted. Overall regional social welfare increased linearly with increasing area under Bt cowpea. In contrast, regional trade volume decreased, because Nigeria—the largest cowpea importer—substituted imports with domestic production. Social welfare of producers outside of Nigeria decreased far more than the increase in welfare of Nigerian producers.

The results suggested that a 10% supply increase through improved yields in only Bean/Cowpea CRSP countries of Burkina Faso, Ghana, and Niger increased

regional trade volume by 9%. Regional prices decreased by 2.9% leading to an increase in demand by 5.7%. When all cowpea producing countries within the NCG benefited from the Bt technology, cowpea traded volume expanded but less than when only Bean/Cowpea CRSP countries benefited due to relatively larger proportionate decrease in regional prices encouraging more consumption of cowpeas. Trade flow changes occurred as countries benefiting from the supply substantially altered their trading patterns compared with those not influenced by the policy. Examination of the distributional effects of generated welfare of US\$182 million (or 3% increase over the base case) suggested that producers in countries with improved yields benefited and all others lost, because those benefiting from the technology sold more cowpea than their counterparts at similar prices. Net regional welfare was over 160% higher when all countries adopted the Bt technology than otherwise.

The results thus emphasize the need for all cowpea producing countries to adopt the technology, if available, to increase regional benefits or risk losing out. The results also draw attention to the need to devise ways to ensure equitable distribution of welfare generated by the policy among producers and consumers.

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### Authors' Notes

This publication was supported by grants to the Bean/Cowpea CRSP by the Office of Agriculture and Food Security, Economic Growth Center, Global Bureau, United States Agency for International Development, under the terms of Grant No. DAN-G-SS-86-00008-00. The opinions expressed herein are those of the authors and do not necessarily reflect the views of the United States Agency for International Development