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Potential Regional Trade Implications of Adopting B_t Cowpea in West And Central Africa

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Abstract

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* (B_t) cowpea (*Vigna unguiculata* (L.) Walp). The results showed that regional cowpea prices would decrease leading to increased demand region-wide and supply in only adopting countries. Total cowpea traded and regional welfare would increase but producers in non-adopting countries would lose. The results thus emphasize region-wide adoption of any B_t cowpea but draw policy makers attention to devise ways of ensuring equitable distribution of benefits.

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

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Introduction

Cowpea (*Vigna unguiculata* (L.) Walp), the most economically important African grain legume is 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). Annually, an estimated 300,000 metric tons of cowpea, which is about 90% of the total official volume entering the African market, is traded within the so called Nigerian Cowpea Grainshed (NCG) (Figure 1) but the actual commerce is probably somewhat much larger (Langyintuo et al., forthcoming). The Economic Community of West African States (ECOWAS), to which many of the countries within the NCG belong (Figure 1), have eliminated all tariffs on agricultural imports but non-tariff barriers such as inefficient transportation services, different currencies, numerous road checkpoints, and unofficial taxes have tendered to increase transaction costs impeding trade (Knowles, 1990; Obadan, 1984; Gambari, 1991; Henink and Owusu, 1998). 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) (initially slated for 2004) where by member countries would use a common currency and monetary policy managed by a West Africa Central Bank (ECOWAS, 2001; Masson and Pattillo, 2001). In their analysis of the potential impacts of the proposed WAMZ on grain trade in the region, Langyintuo et al (forthcoming) showed that if the WAMZ results in reduced real interest rates and trade barriers within ECOWAS, trade volume would increase.

Granted that regional trade policies are effectively facilitating grain flow, cowpea trade volume would still be limited by biotic and abiotic factors that constrain grain supply if not effectively addressed. 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). Average cowpea yields are generally low due to the use of low yielding traditional varieties, poor soil fertility, unfavorable weather, and inefficient crop management practices (Sawadogo, et al., 1985; Diehl and Sipkins, 1985; Montimore et al., 1997; Blade et al., 1997; Singh et al., 1997; SAFGRAD, 1998). Additionally, field pests such as the cowpea pod borer (*Maruca testulalis*), can potentially reduce cowpea pod yields by 17-53% (Liao and Lin; 2000) while bruchids (*Callosobruchus maculatus*), are known to cause between 6 - 60% or more

damage to cowpeas in storage (Golob et al., 1996; Murdock et al, 1997; Langyintuo et al., 2004). Various United States of America and African research institutes working within the auspices of the United States Agency for International Development funded Bean/Cowpea Collaborative Research Support Program (CRSP), among others, are developing high yielding improved cowpea varieties resistant to common biotic and abiotic factors as well as appropriate improved storage technologies (Murdock et al., 1997; Hall et al., 2002; Singh et al., 2002; Fatokun, 2002; Tamò et al., 2002).

Unlike bruchids for which there is potential for genetic resistance from natural sources and non-chemical storage methods (Murdock et al, 1997; Kitch and Sibanda, 2001), there are no known natural sources of resistance for pod borers. Chemical insecticides offer effective control but these products are often not available or too expensive for low income African farmers. On the other hand, when insecticides are available and affordable, they are often misused by illiterate producers. Health problems related to misuse of insecticides (Drafor, 2003; Ajayi and Waibel, 2003; Maumbe and Swinton, 2003) are reasons for considering a genetic solution to the pod borer problem. A more economically and environmentally attractive way to control pod borers is through genetic transformation with *Bacillus Thurengius* (B_t) genes (Machuka, 2002; Sithole-Niang et al., 2001). It is common knowledge, however, that the use of biotechnology in Africa and elsewhere draws huge controversy because of the perceived potential risks of genetic engineering although it is believed that “genetic engineering is as safe as any modern plant breeding technology” (Wilson et al., 2004).

Apart from South Africa, which has been growing genetically modified (GM) crops for some years now, African countries are yet to fully embrace biotechnology but the momentum appears high judging the fact that various countries are at different stages of drafting biosafety regulations (Koch, 2004). In West and Central Africa, Nigeria has developed biosafety regulations and procedures that would allow testing of GM crops (FMANR, 1994; Africast, 2001; GENET, 2002) while the presidents of Niger, Mali, Burkina Faso and Ghana have given their approval to the use of biotechnology to improve food security (USDA, 2004). The establishment of the African Agricultural Technology Foundation (AATF), which aims at promoting both classical plant breeding 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).

The use of biotechnology in West and Central Africa is not a forgone conclusion but given the momentum of governments to embrace GM technology as a means to improve food security as well as the fact that AATF has designated cowpea as one of three crops targeted for improvement using biotechnology (USAID, 2003), this paper assessed the potential impacts of West and Central African farmers within the NCG adopting B₁ cowpea on regional cowpea trade and welfare of cowpea producers and consumers. A spatial and temporal price equilibrium (SPE) model was formulated in a mixed complementary programming framework and solved using GAMS/PATH because of the presence of differential interest rates among countries in the NCG and the *ad valorem* tariff equivalents of non-tariff trade barriers. Cowpea unlike industrial raw material crops is traded within Africa and thus affords the opportunity to make the analysis without worrying about external trade policy implications should B₁ cowpea be adopted on the continent. 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.

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 which relate local production and use to local price, are known. Consequently, the magnitude of exports or imports at each local price is also known (Takayama and Judge, 1971; Harker, 1986). 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 and Yang, 1997; Peeters, 1990; Minot and Goletti, 1998).

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 re-formulated in a mixed complementary programming (MCP) framework, which consists of a set of simultaneous (linear or non-linear) 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 non-linear optimality problems.

It generally complicated to implement the MCP and hence its empirical application in agriculture is scanty. Yang and Page (1993) showed that the impact of an *ad valorem* tax on demand prices is the same for all interrelated spatial regions regardless of their price elasticities. Arndt et al., (2001) used an optic developed by Benirschka and Binkley (1995), to model seasonal flow reversals (or backward transport) under market regimes where storage costs in rural production zones are high. They observed that high storage costs in rural zones induced farmers to sell immediately post-harvest and repurchase late in the marketing season in order to benefit from more efficient storage elsewhere. More recently, Langyintuo (2003) specified an empirical spatial and temporal equilibrium model in a mixed complementary framework suitable for trade policy analysis in the presence of *ad valorem* tariffs and differential interest rates and was applied by Langyintuo et al. (forthcoming) to examine the potential welfare implications of implementing the WAMZ on cowpea trade. They concluded that if implementing the WAMZ resulted in the reduction of real interest rates and trade barriers within ECOWAS, regional welfare would increase but drew the attention of policy makers to the need to devise ways to ensure equitable distribution of welfare among producers and consumers within the proposed WAMZ.

In this study, the MCP formulation derived by Langyintuo (2003) was adopted because countries within the NCG exhibit large differences in interest (or discount) rates (related to the stability of their economies) and the non-tariff barriers between them were best expressed in terms of their *ad valorem* tariffs equivalents. The model is motivated here by first building an integrable SPE model with a constant discount rate through space and time and a specific tariff. The first order conditions with respect to the spatial and temporal arbitrage conditions are then modified to incorporate the differential discount rates and *ad valorem* tariffs, respectively.

Consider R as the set of regions involved in the production and consumption of homogeneous cowpea. Represent the subset of regions producing cowpea by R^s and consuming

regions by R^d . For a total time period T , let T^n be the set of non-harvest periods and t any time period. Let a typical supply or demand market be denoted by r . Denote S_{rt} and D_{rt} as the supply and demand, respectively, at market r in time t . Let $T_{(ijt)}$ denote the nonnegative cowpea shipment between market pair $(i, j) \in W$ (the origin-destination pair), where $i \in R^s$ and $j \in R^d$ in time t . To describe the price and cost structure of the cowpea market, let ψ_{rt} denote the supply price at market $r \in R^s$ in time t , Φ_{rt} the demand price at demand market $r \in R^d$ in time t , and $c_{(ijt)}$ the transportation cost associated with shipping cowpea between market pair (i, j) in time t and assumed fixed. In other words, $c_{(ijt)}$ is independent of the volume of cowpea shipped. Let the quantity of cowpea stored in region r , in time t be K_{rt} at a storage cost of k_{rt} and the prevailing consumer price P_{rt} .

Assuming that ψ_{rt} depends upon the supply of cowpea at region r , then the inverse supply function can be stated as:

$$\psi_{rt} = \psi_{rt}(S_{rt}) \quad \dots (1)$$

Similarly, if Φ_{rt} depends upon the demand for cowpea in region $r \in R^d$ in time t , the inverse demand functions can be stated as:

$$\Phi_{rt} = \Phi_{rt}(D_{rt}) \quad \dots (2)$$

These inverse supply and demand functions assume perfect certainty. Additional parametric notations important in setting up a two-country spatial and temporal equilibrium model are as follows:

- $\gamma_{(ijt)}$ unit specific tariff between countries i and j ,
- $\tau_{(ijt)}$ unit ad valerom tariff between countries i and j ,
- δ discount factor: $\delta = (1 + i)^t$, and
- ϕ storage loss factor (in percent).

Assuming a constant interest rate across space and a specific tariff, the social welfare function that needs to be maximized in the two-country model is:

$$Max_{(D_{rt}, S_{rt}, T_{(ijt)}, K_{rt})} \sum_{t=1}^T 1/(1+i)^t \left(\begin{array}{l} \sum_{r \in R^d} \int_0^{D_{rt}} \Phi_{rt}(\vartheta) d\vartheta - \sum_{r \in R^s} \int_0^{S_{rt}} \psi_{rt}(\xi) d\xi - \sum_{(ij) \in W} \int_0^{T_{(ijt)}} (c_{ijt} + \gamma_{ijt})(\varpi) d\varpi \\ - \sum_{r \in R} \int_0^{K_{rt}} k_{rt}(\omega) d\omega \end{array} \right) \quad \dots (3)$$

Subject to:

$$K_{rt+1} \leq \phi K_{rt} + S_{rt} + \sum_{j \in R^s} T_{jrt} - (D_{rt} + \sum_{j \in R^d} T_{rjt}) \quad \forall r \in R; t \in T \quad \dots (4a)$$

$$D_{rt}, S_{rt}, T_{(ijt)}, K_{rt}, \text{ all } \geq 0 \quad \forall r \in R; t \in T, (ij) \in W \quad \dots (4b)$$

$$S_{rt} = 0 \quad \forall r \in R^d; t \in T \quad \dots (4c)$$

$$S_{rt} = 0 \quad \forall r \in R^s; t \in T^n \quad \dots (4d)$$

$$K_{r1} = 0 \quad \forall r \in R \quad \dots (4e)$$

$$T_{(ijt)}, T_{(jrt)} \text{ both } \geq 0 \quad \forall r \in R^s; t \in T \quad \dots (4f)$$

Now consider a partial lagrangean with respect to strictly positive values of T_{ijt} , and K_{rt} .

$$\frac{\partial L}{\partial T_{(ijt)}} = -(c_{ijt} + \gamma_{ijt}) + \lambda_{jt}(1+i)^t - \lambda_{it}(1+i)^t \leq 0 \quad \text{and} \quad \left(\frac{\partial L}{\partial T_{(ijt)}} \right) T_{(ijt)} = 0 \quad \dots (5a)$$

$$\frac{\partial L}{\partial K_{rt}} = -k_{rt} + (\phi \lambda_{rt} - \lambda_{rt-1})(1+i)^t \leq 0 \quad \text{and} \quad \left(\frac{\partial L}{\partial K_{rt}} \right) K_{rt} = 0 \quad \dots (5b)$$

By interpreting the Lagrangean λ as the optimal price for cowpea in each region, the following economic interpretation can be given to (5a): when the optimal flow $T_{(ij)}$ is positive, the market price in region j , $\lambda_{jt}(1+i)^t$, must exceed the market price in region i , $\lambda_{it}(1+i)^t$, by the unit transportation cost adjusted by the specific tariff, $(c_{(ijt)} + \gamma_{(ijt)})$, and if $T_{(ijt)} = 0$, the market price in region j , $\lambda_{jt}(1+i)^t$, does not exceed the market price in region i , $\lambda_{it}(1+i)^t$, by the unit transportation cost adjusted by the specific tariff, $(c_{ijt} + \gamma_{ijt})$. Condition (5b) states that, at the optimum, when positive quantities are stored, K_{rt} , it must be that the future market

price, $\lambda_{r+1}(1+i)^t$, must be greater than the current price adjusted by storage loss factor, $\phi\lambda_{rt}(1+i)^t$, and the storage cost, $k_{rt}(K_{rt})$, and if $K_{rt} = 0$, then the discounted future market price, $\lambda_{r+1}(1+i)^t$, is not greater than current price, $\phi\lambda_{rt}(1+i)^t$, adjusted by the storage cost, $k_{rt}(K_{rt})$. Notice that the specific tariff and the constant discount factor still allow the SPE model to be formulated as an optimization problem. Therefore, the first order conditions of the complete setup (See Langyintuo, 2003) could thus be solved for demand, supply, storage, prices, volume and direction of cowpea shipment. The traditional SPE set up, however, needs to be modified to account for differential interest rates and ad valorem tariffs (equivalents of NTBs).

Assume a positive, ad valorem tariff (the tariff-equivalents of the NTBs) applied to imports from market i in time t by market j . When the optimal flow $T_{(ij)}$ is positive, the market price in region j , p_{jt} , (where $P_{jt} = \lambda_{jt}(1+i)^t$) must exceed the market price in region i plus the unit transportation cost all adjusted by the ad valorem tariff, $(p_{it} + c_{ijt})(1 + \tau_{ijt})$. This would destroy the integrability of the SPE but can be accommodated by modifying the first order conditions with respect to the inter-spatial arbitrage condition (5a) as follows:

$$(p_{it} + c_{ijt})(1 + \tau_{ijt}) \geq p_{jt} \quad \dots (5a')$$

Similarly, real interest rates differentiated through space would destroy the integrability of the traditional SPE. This could be visualized as similar to an ad valorem tariff through time. Differential interest rates may be accounted for by adjusting the inter-temporal arbitrage condition (5b) as:

$$-k_{rt} + (\phi\lambda_{rt} - \lambda_{r-1})(1+i_r)^t \leq 0 \quad \dots (5b')$$

By letting $P_{rt} = \lambda_{rt}(1+i_r)^t$, (5b') can be expressed as $\phi p_{rt} \leq p_{r-1} + k_r$. This states that, at the optimum, when positive quantities are stored, K_r , it must be that the future market price discounted by the region specific discount rate, $\lambda_{r+1}(1+i_r)^t$, must be greater than the sum of the

loss factor-adjusted current price and storage cost all adjusted by the region specific discount rate, $(\phi\lambda_{rt} + k_r)(1 + i_r)^{t+1}$.

The model was formulated as a four-period MCP in the General Algebraic Modeling System (GAMS), with five blocks of equations and five sets of endogenous variables for each of the 11 countries, and solved using GAMS/PATH solver (Brooke et al., 1992; Dirkse and Ferris, 1995). A one-year model was considered because inter-annual storage volumes of cowpea tend to be negligible (Langyintuo, 2003).

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: B_t cowpea is assumed to be adopted in only Nigeria, on only 10% of the cowpea area initially but gradually increased to 100%. Since any B_t cowpea varieties would have to be multiplied and distributed to farmers, it is assumed that initially only 10% of the area is planted to B_t cowpea and subsequently increased to 100%. But please note that refuge requirements¹ usually limit the proportion of area planted to B_t crops to 50% to 80% of area planted, so the 100% scenario is included mainly as a theoretical limit. The Bean/Cowpea CRSP has broad-based interdisciplinary programs in Burkina Faso, Cameroon, Ghana, and Niger and only marketing research in Nigeria and work closely with AATF. This can be a basis for farmers in the target countries to benefit from B_t cowpea technology earlier than their counterparts in the other countries. Therefore in Scenario 2, it is assumed that B_t cowpea be adopted in only the Bean/Cowpea CRSP countries on limited cropped areas but enough to result in a 10% increase in aggregate yields. Scenario 3 assumed that B_t cowpea be adopted in each cowpea producing country within 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 and corresponding prices in surplus producing countries were lower than those in deficit ones.

¹ Refuge requirements for B_t crops are used to help reduce the development of pest resistance. Non-resistant insects continue to reproduce in the refuges and hence dilute the selection pressure. Studies focused on setting refuge requirements for B_t cowpea are underway, but percentages have not yet been established. It is also assumed that there are no barriers to trade for B_t cowpea.

Whereas supply and demand elasticities were obtained from 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 and transportation losses assumed to be 1% per each shipment. Following Golob et al., (19967), a 15% storage loss factor was assumed for a quarter.

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 (Lowenberg-DeBoer, et al., 1994; Evers and Mehmet, 1994; Basu, 1997; Warning and Sadoulet, 1998; Bose, 1998) for reasons such as traders simply not considered credit worthy (Bose, 1998) and rationing of credit to traders (Kochar, 1997; Chakrabarty and Chaudhuri, 2001). 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 and 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 thereby increasing the supply in the surplus region reducing prices, while decreasing supply in the deficit region, thus increasing prices. The net effect is to increase the price differential between the two regions. Information on the degree of restrictions on non-traditional 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 road blocks 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. 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 functions², 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 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%), Cote 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 valerom* 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 non-linear 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% 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 lost in welfare to producers and consumers through non-tariff barriers was equivalent to about US\$12 million, or 0.2% of net social welfare. Total surplus per capita 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

² In a similar setting, Langyintuo (2003) observed the linear functions to be better fit than alternative functions.

farming population, Niger is first with US\$208 followed by Mali with US\$83 and third by Nigeria and Benin with US\$26 each. Cote d'Ivoire is the least with only US\$2.4.

The potential impacts of B_t cowpea being adopted in only Nigeria

In this scenario, it was assumed that yields from B_t cowpea were 100% more than the current farm level yield of 494 kg/ha (Sing et al., 1997). As farmers increased the area under B_t cowpea in Nigeria, regional prices decreased from 8% when 10% of the area was under B_t cowpea to 62% with 100% area under B_t cowpeas (Table 4). At 80% area under cowpea, a typical refuge requirement for cowpea, regional prices are reduced by about 48%. This resulted in an increase in consumer demand region-wide. Because consumers in Nigeria increased their demand corresponding to the lower prices, Nigeria only began to export³ cowpea when at least 80% of the cowpea area was under B_t cowpea. The increase in Nigeria's domestic supply forced Niger to re-direct 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.

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 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 B_t cowpea (Figure 2). Figure 3 shows that below 20% of the area under B_t cowpea, consumers welfare gain was less than producer welfare gain in value terms. Beyond 20%, however, consumer welfare gain was greater than the producers welfare gain and continued to increase at a linear rate while the former increased at a decreasing rate.

³ At 85% of area under B_t cowpea, Nigeria exports an estimated 26t of cowpea to Cameroon. This increases to about 1,000 t, 1,800 t, 2,300 with 90%, 95% and 100% area under B_t cowpea, respectively.

Potential impacts of B_t 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 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 comparative 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 was 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 improvement in total welfare except in Chad where the lost in producer welfare outweighed the gain in consumer welfare so much so that total welfare decreased by 0.5%.

Potential impacts of B_t cowpea adopted in all countries within the NCG

When a 10% yield shock affected all countries in the NCG, 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 Cote 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 pest especially pod borers (*Maruca testulalis*) and the storage weevil *Maruca*. Whereas natural sources of genetic resistance to cowpea storage pests are available, genetic transformation with *Bacillus Thuringiensis* (B_t) genes offers an economically and ecologically sustainable way to combat pod borers for which there is no natural sources of resistance. Using a spatial price equilibrium model, this study examined the potential impacts of farmers in Benin, Burkina Faso, Cameroon, Cote d'Ivoire, Gabon, Ghana, Mali, Niger, Nigeria, and Togo within the Nigerian Cowpea Grainshed (NCG) adopting B_t cowpea on cowpea price, direction and volume of cowpea trade, and regional social welfare.

The simulation of a B_t 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 B_t varieties, which appears unlikely because of refuge requirements that typically limit B_t crops to less than 80% of area planted. Overall regional social welfare increased linearly with increasing area under B_t 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 B_t 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 B_t 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, but also draw attention to the need to devise ways to ensure equitable distribution of welfare generated by the policy among producers and consumers. Finally, this paper contributes to the literature on the application of spatial and temporal models in regional policy.

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

	Supply		Quarterly demand		Demand price	
	('000 t)	% deviation from benchmark	('000 t)	% deviation from benchmark	(US\$/t)	% deviation from benchmark
CRSP Countries						
Burkina Faso	135.27	10.91	6.48	-15.84	527	31.91
Cameroon	51.45	0.16	9.33	1.64	404	-7.43
Ghana	77.53	10.00	41.00	-3.00	565	7.33
Niger	681.44	5.66	8.45	-8.03	533	40.63
Non-CRSP Countries						
Benin	78.46	3.36	13.34	-3.05	534	7.48
Chad	18.29	1.42	2.81	-0.11	429	-0.31
Cote d'Ivoire	18.76	5.49	20.79	-6.14	602	16.89
Gabon	-	-	0.53	16.78	458	-47.96
Mali	113.09	2.12	16.06	-4.08	529	16.10
Nigeria	2,346.34	10.62	654.99	-3.88	591	14.60
Togo	33.43	4.47	10.15	-2.37	555	6.90
Total/average	3,554.06	8.90	783.93	-3.94	-	-

Table 2: Optimal interregional cowpea shipment in the base case ('000 t)

Exporter	Importer	Jul - Sep	Oct - Dec	Jan - Mar	Apr - Jun
CRSP Exporting Countries					
Burkina Faso	Cote 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	-	-
Non-CRSP Exporting Countries					
Benin	Nigeria	-	-	-	7.63
Benin	Togo	-	-	-	6.75
Mali	Cote 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 (US\$ million)

	Consumer surplus	Producer surplus	Total surplus	Producer surplus per farmer	Total surplus capita ⁻¹
	----- (US\$ millions) -----			----- (US\$) -----	
CRSP Countries					
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
Non-CRSP Countries					
Benin	19.95	101.36	106.14	25.96	17.40
Chad	2.42	27.66	29.39	4.26	7.59
Cote 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
Total	2,364.91	4,506.27	6,269.31	27.94	-

Note: *Tariffs and tariff-equivalents of non-tariff barriers
 - No value

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

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

Note: * Gabon does not produce cowpes

**The weight was the proportion of cowpea demanded or supplied by country

- No figure

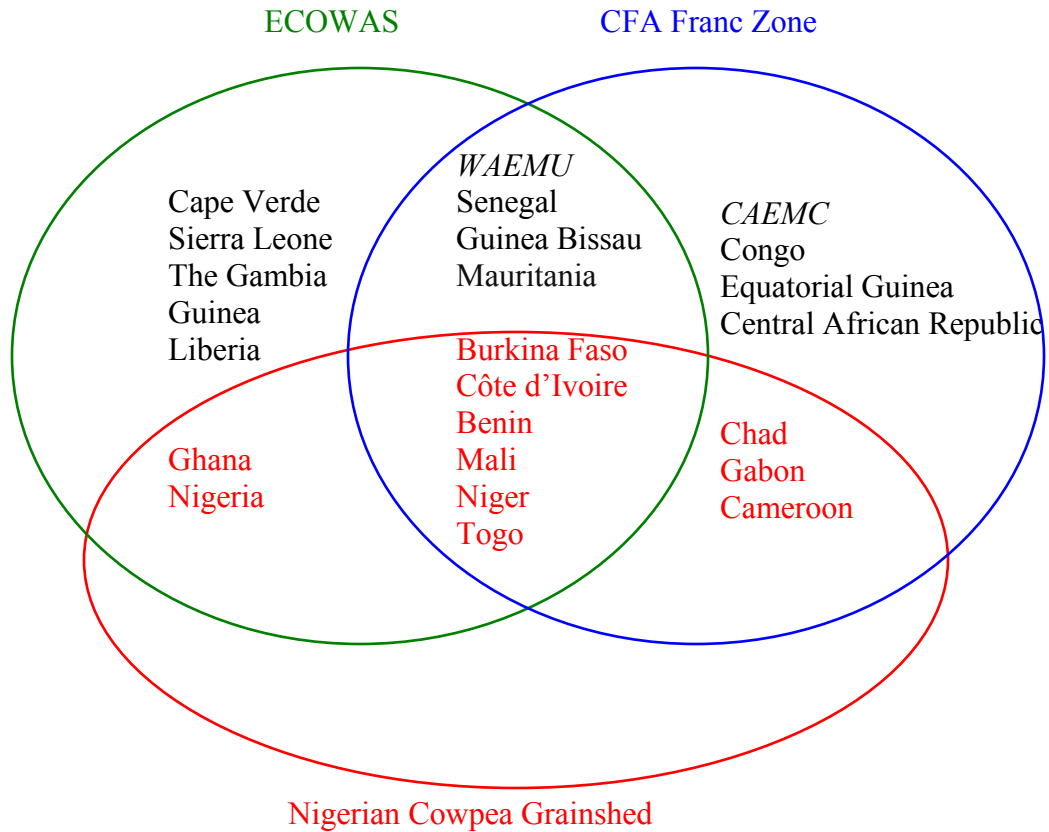


Figure 1: Membership of ECOWAS, CFA Franc Zone and Nigerian Cowpea Grainshed

Source: Langyintuo et al. (forthcoming).

Note: Ghana, Burkina Faso, Niger and Cameroon belong to the Bean/Cowpea CRSP countries.

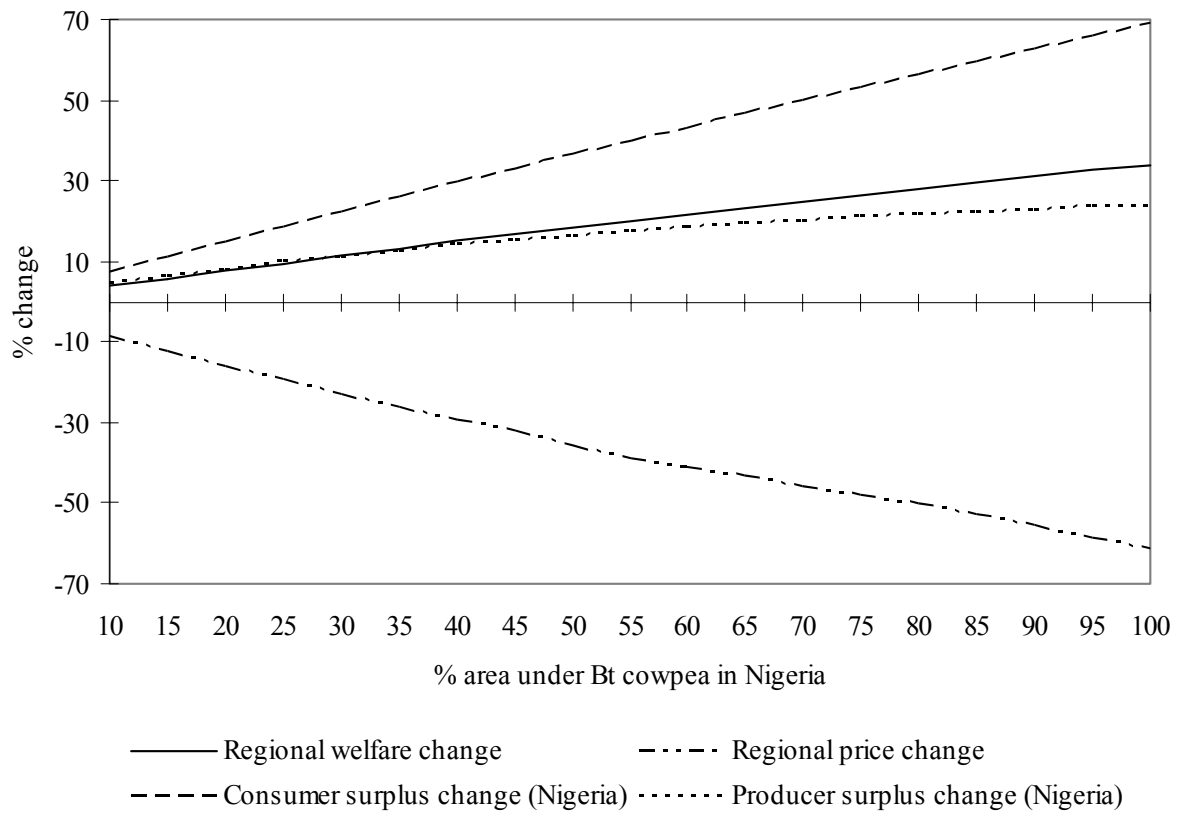


Figure 2: Simulation results showing percentage changes in parameters given changes in area under B_t cowpea in Nigeria

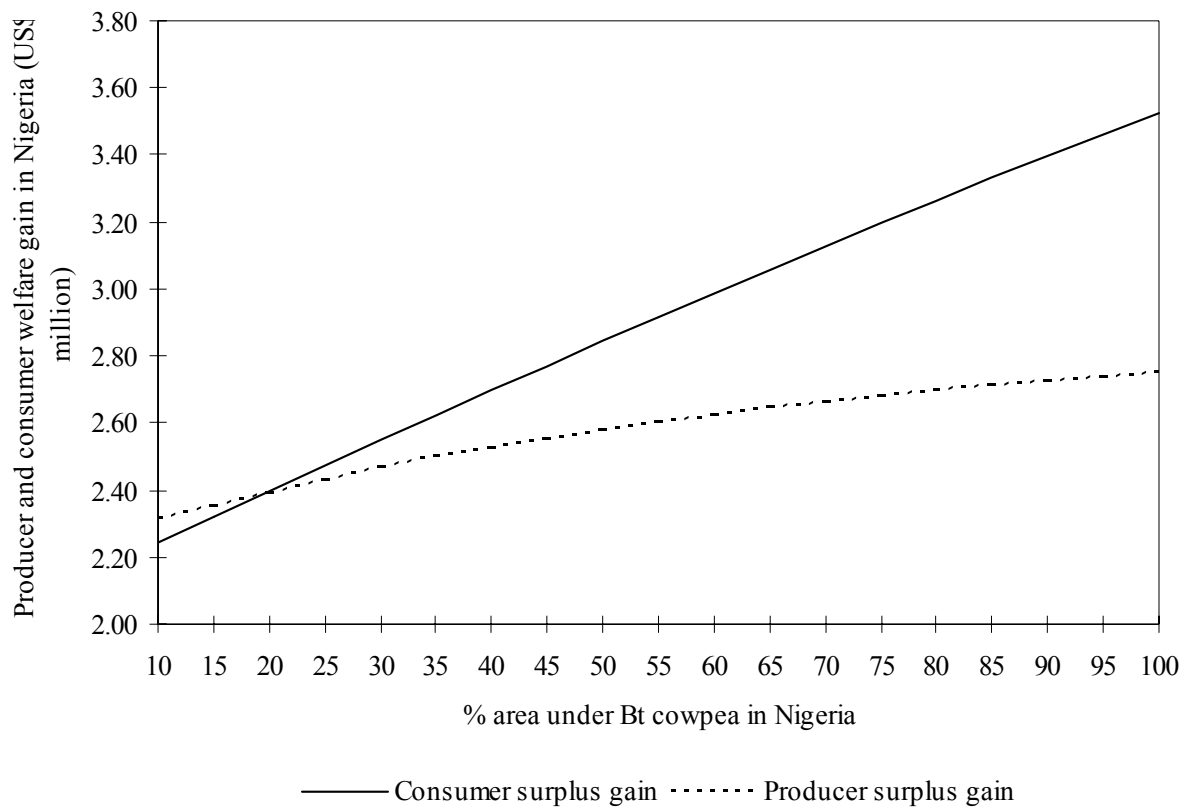


Figure 3: Simulation results of changes in producer and consumer welfare gains within Nigeria given changes in area under B_t cowpea in Nigeria alone