

Effects of More Open Trade on Cattle Production, Beef Consumption, and Welfare in the Central Corridor of West Africa

by

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ABSTRACT

The magnitude and direction of trade flows in cattle and beef, and how cattle production and beef consumption adjust in response to more open trade in the Central Corridor (an acronym for the sub-region that includes Ghana, Cote d'Ivoire, Mali, and Burkina Faso) have been estimated. A mathematical programming approach was used to model trade in cattle and beef in the West African Central Corridor. Quadratic programming which maximizes the net social surplus in the Samuelson sense under a competitive market framework when farmers are risk averse was applied. Estimates of consumer surplus, producer profits, and government revenue changes were used as welfare indicators. The different scenarios analyzed indicate that there would be an increase in trade in cattle and beef consumption in the sub-region, as well as an overall welfare gain.

Introduction

This study analyzes the implications of creating a free-trade zone for cattle among West African countries, which is one aspect of the ongoing economic integration discussion in

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the sub-region. The analysis focuses on trade arrangements that allow free movement of cattle² among the countries constituting the Economic Community of West African States (ECOWAS), while each country sets its own trade policies with non-members.

Historically, cattle have been an important item of trade among ECOWAS countries, particularly between the Sahelian (semi-arid north) and coastal (humid south) countries. Trade flows have generally been in a north-south direction, and movements across coastal countries have been uncommon, except for some beef and other cattle products in limited quantities. The study covers cattle trade in the “Central Corridor”³ of West Africa, where the dumping of beef from the European Union has been high in recent years (Madden, 1993). Fig. 1. shows cattle trade flows as it has historically existed in the subregion, including beef imports from the European Union in recent years. The lighter arrows indicate limited trade in processed beef (e.g., smoked beef and hide) and other cattle products (e.g. leather).

Inter-regional trade within the West African sub-region has been limited, averaging less than 10% of total trade, compared to about 70% for Western Europe and 40% for NAFTA (Sander, 1996). Some of the reasons given for the failure to expand trade among West African countries include: (1) the lack of political will on the part of governments to sacrifice inefficient domestic production in favor of cheaper imports from countries in the sub-region; (2) balance of payment problems resulting from significant differences in macroeconomic policies; (3) large differences in economic size and levels of development such as between coastal and interior states; (4) similarity of products and high transaction costs; and (5) structural and historical factors emanating from different colonial experiences and

²Even though most of the cattle in the sub-region are raised for beef, they are generally dual-purpose animals. This study concentrates on the beef aspect of the cattle sub-sector.

³The “Central Corridor” is a short-hand term for the four countries situated in the central part of the West African sub-region: Ghana, Cote d’Ivoire, Mali, and Burkina Faso.

economic traditions.

However, the core of all these problems seems to be the lack of information on the specifics, such as the magnitude of expected changes that will be generated in goods and services as a result of economic integration. Even though the ECOWAS treaty advocated, in general terms, more open trade across borders in the sub-region, each country has both tariff and non-tariff barriers which negatively affect trade among them. At the official level, most forms of export taxes and import tariffs on cattle and other livestock products have recently been removed or substantially reduced by all the countries in the Central Corridor. However, other forms of taxes still persist, both at the official and unofficial levels. These include market taxes, veterinary taxes, sales tax, and various forms of certification and licensing fees which together constitute substantial transaction cost.

Kulibaba and Holtzman (1990), for example, report the existence of several types of payments along the marketing chain for livestock in the central corridor, including tips to government officials (or what they term as payment for licit services), bribery (or payment for illicit services), extortion, and fraud. The aggregate of these costs could be very substantial, thereby impinging on the benefits that would otherwise have accrued to free trade in cattle in the sub-region. There is thus a significant gap between what is theoretically desirable at the official level and what pertains in actual practice of more open trade in cattle in the sub-region.

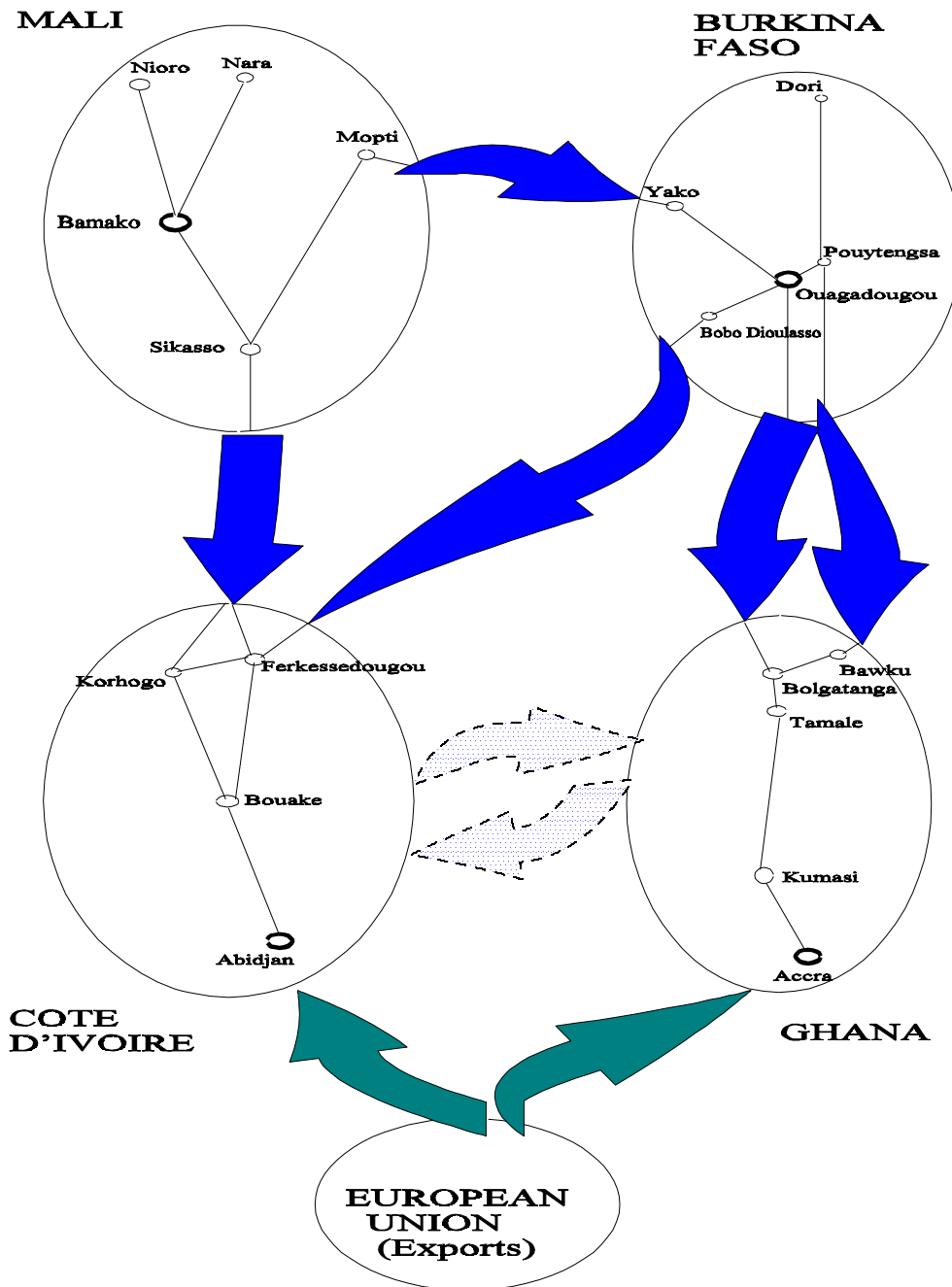


Figure 1. Beef and Cattle Trade Flows in the Central Corridor of West Africa.

The foregoing generates some interesting questions: What would be the direction of shifts in the production of cattle and consumption of beef under free trade in the region? What would be the distribution of gains and losses (*i.e.*, who would be the gainers and losers) when there is more open trade? What would be the magnitude of these changes? How would the flow of beef imports to the sub-region change, and what would be its implication for import substitution in the region? Would a common currency or a common exchange rate regime for the sub-region make any difference to cattle trade flows in the Central Corridor? To inform these questions, there is need to investigate what would happen to the production of cattle and consumption of beef in the sub-region if all intra-regional trade restrictions were removed, and what would be their implications for regional food imports, particularly beef, under a common currency system.

The main objective of this study is to estimate the magnitude and direction of trade flows in cattle and beef consumption, and their associated welfare implications in the event that more open trade is instituted in the West African sub-region. The specific objectives include: (a) determining the magnitude and direction of shifts in the production of cattle and consumption of beef under more open trade based on comparative advantage; (b) estimating changes in the producer and consumer surpluses for the beef sub-sector in the countries being studied; (c) determining what effect more open trade will have on beef imports into the sub-region; and (d) determining how exchange rate adjustments may cause shifts in the production of cattle and consumption of beef.

Conceptual Framework

The constrained social surplus maximization is a tool that allows one to use mathematical programming methods to analyze the market within a competitive market

framework. When the objective function is maximized, the model generates optimal values for all prices and factors of production and outputs of commodities included in the model at the point where the market is in equilibrium. These values represent the production and consumption levels of the economy modeled, and allow one to compute the consumer and producer surpluses as welfare indicators. Hence, the model provides a convenient way for conducting simulation analysis for a sector of an economy at the country or regional level when a competitive market framework is an appropriate representation as in the case of beef and cattle trade in the central corridor of West Africa.

This study has therefore attempted to model the beef and cattle sector in the Central Corridor of West Africa using a mathematical programming approach. It applies a competitive market framework as a tool to determine the magnitudes of gains from trade and how such gains are distributed among economic agents. The idea is to consider the Central Corridor of West Africa as a trading area which satisfies the competitive market assumption (e.g., homogenous product, and large number of sellers and buyers) with respect to cattle trade. The net social welfare that is generated from demand for beef at the country or regional level is then maximized for the case where no trade barriers exists, and the common regional currency scenario, etc, using a quadratic programming model. Note that maximizing the “aggregate profit” of the sector being analyzed is, in principle, taking the algebraic sum of the profit maximizing problems of the individual producers in the sector. This implies that the total production generated by each activity is determined at the level of each producer’s decision on output based on the individual’s profit function first order conditions. When demand and supply relations are incorporated into the model we obtain the competitive market equilibrium which helps us estimate the producer and consumer surpluses (or net social benefit). McCarl and Spreen (1980) provide a more formal discussion on how maximizing net

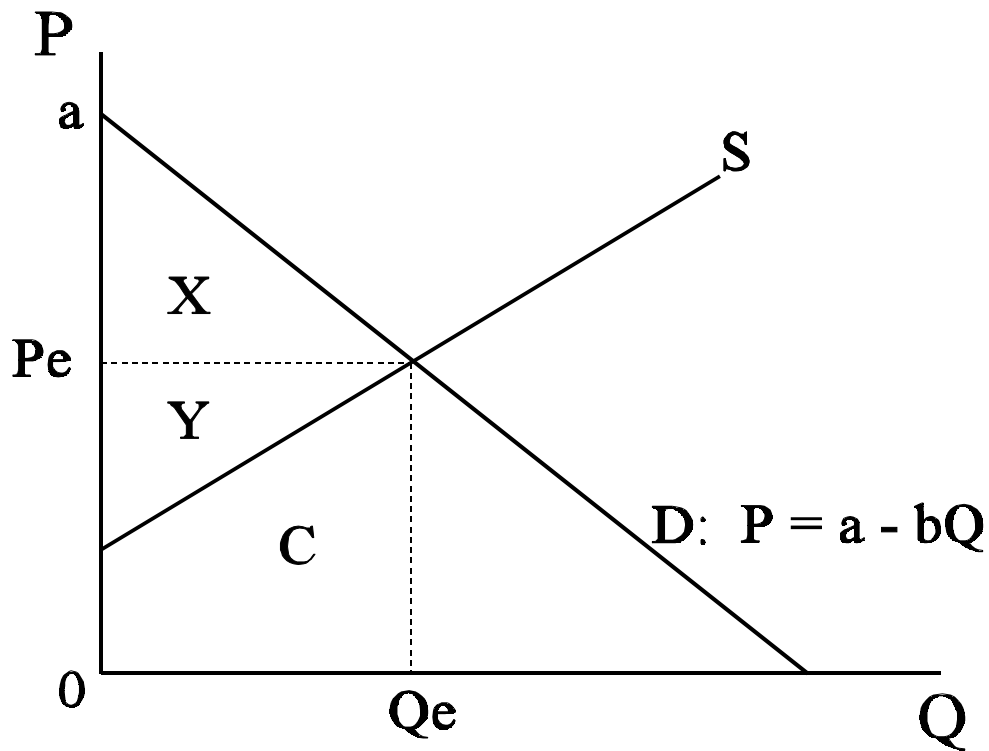


Figure 2.1 Maximizing Net Social Benefit ($X + Y$)

social benefits in the aggregate is analogous to maximizing profits and utility of individuals.

Graphically, the Net Social Benefit (**NSB**) can be shown in a simple market demand and supply framework as in Fig. 2. The Net Social Benefit, **NSB**, is the sum of **X** and **Y** (Fig. 2.1) which are the consumer's and producer's surpluses, respectively. **C** represents the total cost function $C(Q)$, and P_e and Q_e are equilibrium price and quantity, respectively. The NSB associated with any commodity y can be derived by taking the integral of the total area under the demand curve from 0 to Q_e (we substitute for the price-dependant demand function), and subtracting area **C**.

For a linear demand curve, the procedure is as follows:

$$NSB_y = \int_0^{Q_y} P_y \delta Q_y - C(Q_y) \quad (1)$$

$$NSB_y = \int_0^{Q_y} (a_y - b_y Q_y) \delta Q_y - C(Q_y) \quad (2)$$

$$NSB_y = a_y Q_y - 1/2 b_y Q_y^2 - C(Q_y) \quad (3)$$

Similarly, we can derive the NSB algebraically using Fig. 2 by computing area X plus area Y (i.e. NSB) as follows (assuming linear demand and supply functions):

$$NSB = 1/2(a - P_e)Q_e + P_e Q_e - C \quad (4)$$

Then for one commodity, y , we get

$$NSB_y = 1/2(a_y - P_y)Q_y + P_y Q_y - C(Q_y) \quad (5)$$

Substituting for $P_y = a_y - b_y Q_y$ and simplifying:

$$NSB_y = a_y Q_y - 1/2 b_y Q_y^2 - C(Q_y) \quad (6)$$

As seen from equations (3) and (6), maximizing the NSB as an objective function implies maximizing a quadratic function, which justifies the use of quadratic programming for the analysis. The equilibrium values generated by the model (e.g. prices and quantities) also represent the decision variables that determine changes in production and consumption, as well as welfare.

Analytical Model

Sectoral analyses based on mathematical programming have examined the effects of various policies on foreign trade in both developed and developing countries. For example,

Cappi *et al.* (1978) discuss trade volume restrictions within agricultural production and trade in the context of economic integration in Central America; while Duloy and Norton (1979) explore comparative advantage implications for Mexican agriculture. Similarly, Meister *et al.* (1978) study changes in agricultural export levels using a quadratic programming model; and Rodriguez and Fajardo (1979) analyze sectoral response to changes in the prices of agricultural exports and imports. More recently, Worley *et al.* (1991) have applied mathematical programming to examine the implications of Canada - U.S. free trade agreement for red meat and grain in both countries. The available volume of literature thus indicates that in simulating the potential sectoral effects of new economic policies, mathematical programming models have proved very useful, as evidenced in the review by Blitzer *et al.* (1975).

In the present study, local beef, imported beef, and cattle are considered, so that the quadratic programming model is essentially a simulation model of the cattle industry within a competitive framework, allowing changes in both the objective function and constraints (*e.g.*, changes in government policies or some external shock) with endogenous adjustment by economic agents. The net social benefit, which is the net social payoff, is defined here in the Samuelson tradition as the sum of the separate payoffs from each activity considered, less the total costs of all the activities.

A base year solution was obtained using the base year data, which was 1993 in this case (1993 was chosen due to data availability, and because it was the last year of the pre-devaluation period for the CFA Zone countries). The model is considered to have converged if (a) the results from the model accurately replicate the respective country/region's production, consumption, and trade levels for the base year; (b) the prices and quantities demanded for beef in the base year were replicated; (c) numbers of cattle produced in the base

year were reproduced for each country/region; and (d) the base period solution was sensitive to beef demand elasticities (McCarl and Spreen, *ibid.*). Once the model is validated, the expected policy changes are then incorporated. The optimal solution provides estimates of consumer and producer surpluses, prices, quantities of beef produced, consumed, and traded; as well as herd of cattle produced and traded; which are then compared with the base period.

The quadratic programming applied in this analysis maximizes a non-linear objective function (a polynomial of the second degree) subject to a set of linear constraints, with all the variables defined for non-negative values. This is a special case of the general non-linear programming models with well-developed solution methods that overcome the existence of multiple local maxima and minima which are often associated with non-linear models. By using a quadratic objective function, the model also avoids the assumption of perfect elasticity of supply and demand for commodities which is inherent in the linear objective functions when linear programming is applied to economic problems.

A major advantage of applying mathematical programming to analyze trade flows is that it permits both the analysis of a single commodity in a multi-country/region context, and the incorporation of multiple commodities and multiple regions/countries in a single model, while at the same time preserving the theoretical elements inherent in real trade models. For this quadratic programming model, in which net social benefits are maximized within a competitive market framework, the decision variables include regional/country levels of cattle production, beef consumption, shipments, and imports which are determined within the model. Each region/country defined has a linear demand function for beef incorporated into the model, while the total number of hectares of available pastoral land per region/country, the number of cattle a hectare of pastoral land can support, and other accounting rows constitute the constraints.

The maximization problem is specified as:

$$\begin{aligned}
Max\ NSB = & \sum_j \int_0^{Q_j^D} P_j^D \delta Q_j^D - \sum_s Q_s^S * F_s^C * C_s^P - \Phi(Q' \Omega Q)^{1/2} \\
& - \sum_s \sum_j \sum_t^4 X_{sjt} * D_{sjt} * T_t \\
& - \sum_j \sum_s X_{sj} * MC_s * MC_j * F_s^C \quad (7)
\end{aligned}$$

Subject to the following constraints:

$$\sum_s X_{sj} * F_s^C = Q_j^D; \quad j=1, \dots, J \quad (8a)$$

$$\sum_j X_{sj} = Q_j^D; \quad j=1, \dots, J \quad (8b)$$

$$\sum_s \sum_t X_{sjt} = \sum_s X_{sj}; \quad j=1, \dots, J \quad (9a)$$

$$\sum_j \sum_t X_{sjt} = \sum_j X_{sj}; \quad s=1, \dots, S \quad (9b)$$

$$R_s^A * Q_s^S \leq A_s; \quad s=1, \dots, S \quad (10a)$$

$$R_s^L * Q_s^S \leq L_s; \quad s=1, \dots, S \quad (10b)$$

$$R_s^K * Q_s^S \leq K_s; \quad s=1, \dots, S \quad (10c)$$

$$P_j^D, Q_j^D, P_s^S, Q_s^S, X_{sjt} \geq 0$$

The variables in the model are interpreted as follows:

- NSB = aggregate consumer and producer surplus measures for beef in a region or country
- j** = demand/consuming region/country
- s** = supply/producing region/country
- t** = mode of transport: **t**₁ = truck; **t**₂ = trek, **t**₃ = train; **t**₄ = plane
- Q_j^D = equilibrium quantity of beef demanded in country/region **j**
- P_j^D = represents the price-dependent demand function for beef in region/country **j**;
(where $P_j^D = a_j - b_j Q_j^D$)
- Q_s^S = head of cattle supplied from producing country/region **s** if **s** = African region/country; or
= quantity of beef supplied from abroad if **s** = world market.
- X_{sjt} = cattle shipments from supply region/country **s** to demand region/country **j** by mode of transport **t** if **s** = African region/country; or
= quantity of beef shipments from abroad if **s** = world market.
- D_{sjt} = distance in kilometers from supply region/country **s** to demand region/country **j** by mode of transport **t**, where **t** = **1, 2, 3, 4**
- F_s^c = conversion factor of each animal to ton beef
- C_s^P = cost of production per ton beef from supply region/country **s**
- T_t = unit cost per kilometer for mode of transport **t**, where **t** = **1, 2, 3, 4**
- MC_j = marketing cost per ton beef (sum of transformation cost and distribution cost) in demand/consuming region/country **j**
- MC_s = marketing cost per head of cattle in supply/producing country **s**
- R_s^A = land (hectares) requirement for cattle production in supply/producing country **s**

- R_s^L = labor (man days) requirement for cattle production in supply/producing country s
 R_s^K = capital requirement for cattle production in supply/producing country s
 A_s = land (hectares) endowment for cattle production in supply/producing country s
 L_s = labor (man days) endowment for cattle production in supply/producing country s
 K_s = capital endowment for cattle production in supply/producing country s
 $\Phi(Q'\Omega Q)^{1/2}$ = expression that accounts for risk-averse behavior of producers

The objective function (Equation (7)) measures the sum of the total area under the demand curve for beef for each country/region considered, less the costs representing the determinants of the aggregate supply function for each activity:

Objective function = Consumer Utility - Production Cost - Transportation Cost - Transformation/Marketing Cost; subject to: cattle off-take numbers at supply centers, land, labor, and capital requirements for production, and factor endowments.

At the optimal solution, one can estimate the net social benefit change relative to the base period as a change in welfare measure. As described below, the welfare measures accruing to economic agents in each country/region are estimated using parameters generated within the objective function for the optimal solution.

Equations (8) to (10) represent the constraints which give form to the model. For example, Equations (8a) and (8b) state that the sum of the total number of cattle produced and transformed into beef in all countries/regions plus all beef imports should equal the total quantity of beef demanded in all countries/regions. Similarly, Equations (9a) and (9b) ensure that shipments of cattle and beef by all modes of transport are equalized between production and demand or consuming centers. Equations (10a), (10b), and (10c) represent land, labor, and capital constraints, respectively, in all producing countries/regions.

Since price equates marginal cost in the set of competitive markets in the trade model, for these markets the implicit aggregate supply functions define costs of production that include both the explicit costs of production and the opportunity cost of owned resources. As multiple regions/countries compete to produce the same commodity, less favorable areas with higher production costs are brought into production as output expands. The result is an upward sloping stepped supply function which is implicit in a sector model with multiple production centers (see Hazel and Norton, 1986). The optimal solution of the model gives estimates of beef cattle numbers per country/region; and also provides information on the transportation network among supply and demand centers. The analysis is based on a long run-scenario, allowing time for changes in government policies to take effect.

Measuring Consumer and Producer Surpluses

The quadratic programming model provides a measure of aggregate consumer surplus (the model sums up all the consumer surplus measures from demand for beef from both domestic and regional sources, as well as imports from the European Union). Hence, an explicit measure of the consumer surplus (as a measure of consumer welfare) for each demand country/region is warranted. This is accomplished using equation (11), which is derived from the maximization of consumer and producer surpluses within a simple demand-supply framework. The price and quantity parameters are endogenously determined within the quadratic programming model.

$$ACS_j = \sum_i (a_i - 1/2b_i Q_i^*) Q_i^* - P_i^* Q_i^* \quad (11)$$

where ACS_j is the aggregate consumer surplus for country/region j ; P^* and Q^* are optimal prices and quantities, respectively, for beef from each source i demanded in the respective consuming country/region; and a and b are the intercept and slope parameters, respectively,

for each demand function.

Similarly, in the case of the Central Corridor, estimates of producer profits were used as indicators of producer gains since pastoral lands are mostly communally owned and have no functioning markets, or at best existing land markets are only rudimentary.

In addition, estimates of the changes in government revenue were made to give some indication of what effect changes in the patterns of cattle trade in the Central Corridor could have on government budgets for the different countries. These estimates were computed using the cattle export or import figures and the relevant taxes, as well as quantities of beef imports and the respective tariffs of each importing country. Also, estimates of other transfers, such as tips and bribes cattle traders pay along the trade routes, were computed.

In order to ascertain how stable the model results were, sensitivity analysis was conducted by changing the price elasticity of demand for each consuming country/region by 10% up and down (i.e. 10% increase in one case, and 10% decrease in another). In general, the price and quantity values endogenously determined by the model compared well with the reported 1993 data for each country in the Central Corridor, thereby validating the model.

Eight cattle producing regions were identified (based on cattle stocks in the 1990s) for the central Corridor – two in Mali, three in Burkina Faso, two in Ghana, and one in Cote d'Ivoire. Some of these regions were then combined in each country because only minimal differences in cattle production existed across such regions within the same country; and also to simplify the model and make it more tractable. Four producing regions, one in each country, were finally specified for the model. These included Mali (Zone Centre-Est and Zone Nord), Burkina Faso (Zone Amenagee, Zone Cotoniere, and Zone Sahelienne), Ghana (Northern Zone), and Cote d'Ivoire (Zone Nord).

On the other hand, there were six consuming or demand regions specified – one in

Mali (all Zones), one in Burkina Faso (all Zones), two in Ghana (all Zones), and two in Cote d'Ivoire (all Zones). The two demand regions each specified for Ghana and Cote d'Ivoire reflected the savannah north in each country where cattle production is important, and the forest south where it is not.

Results of the More Open Trade Model

The more open trade scenario represented the case where all four countries (Mali, Burkina Faso, Ghana, and Cote d'Ivoire) had all existing cattle trade barriers (representing about 10% of the average price of cattle in the region) removed so that trade among them proceeded as if the whole sub-region was a “single” country; except that Ghana retained her own currency. Under this scenario (Table 1), off-take numbers increased relative to the base model figures for Mali (2%), Burkina Faso (11%), and Ghana (11%); but declined for Cote d'Ivoire (28%). However, slaughter figures decreased for Mali (2%), and Burkina Faso (1%); while it increased for Ghana (16%), and for Cote d'Ivoire (2%). On the other hand, the price per head of cattle⁴ in the production regions increased for all four countries between 15% and 19% relative to the base model values.

These increases in off-take figures suggest that more open trade could generate increases in cattle production in the sub-region, even though cattle production in Cote d'Ivoire would decline as cheaper imports of cattle are substituted for local production. Cattle farmers in particular stand to gain in all the four countries, with demand-driven increases in cattle prices at the production centers, even though the case of Cote d'Ivoire is not clear because fewer local cattle would be produced. It implies also that only more efficient cattle producers

⁴Cattle produced in Mali and Burkina Faso were assumed to be of the larger *Zebu* breed (about 250 kg live-weight), while those produced in Ghana and Cote d'Ivoire were the smaller *WASH* and *Baoule* breeds (about 165 kg live-weight).

in Cote d'Ivoire would survive if the sub-region adopted a more open trade in cattle; in which case, higher prices for local cattle could bring higher average returns to farmers.

Also, the decline in slaughter figures in the cattle exporting countries (Mali and Burkina Faso) while those in cattle importing countries (Ghana and Cote d'Ivoire) increased was expected. Consistent with theoretical expectations, the more open trade increased competition from coastal markets in the importing countries, and allowed cattle traders to ship more cattle there which reduced local slaughter.

In terms of exports (Mali and Burkina Faso) and imports (Ghana and Cote d'Ivoire), more open trade increased the volume of trade in cattle as well as beef consumption in all four countries. Total exports from Mali to both Ghana and Cote d'Ivoire increased by 9% relative to the base model; and those from Burkina Faso increased by 28%. This increase in exports from Burkina Faso could include some re-shipments from Mali and/or Niger which the model did not specifically separate out.

At the same time, beef consumption decreased in Mali and Burkina Faso by 3% in each case (beef demand quantities adjust with beef price changes), as higher export demand and higher cattle prices at the production centers encouraged farmers to send more cattle to the market (note that the model assumes a downward sloping demand function and an upward sloping stepped supply function), and traders to export more cattle. Consumers in the exporting countries were therefore hurt as beef prices slightly increased (0.2% in both Mali and Burkina Faso) and thereby decreased beef consumption in the two countries (by 2% in Mali and 1% in Burkina Faso). The results of the more open trade model thus suggest that as trade barriers are removed, substantial portions of savings accruing to traders and marketing agents are passed on to cattle producers, who gain at the expense of beef consumers in the exporting countries. On the other hand, beef prices remained stable in importing countries

while cattle prices increased at the cattle production centers in those countries, because demand increased for all animals, both the larger animals from the Sahel region and the smaller local cattle, which then benefitted local producers.

As already noted, increases in the volume of cattle trading resulted in increased imports of cattle to both Ghana and Cote d'Ivoire. While imports to Southern Ghana increased by some 32% compared to the base model, those to Northern Ghana increased by only 7%; apparently because more open trade allowed more access to markets in Southern Ghana, where beef demand has been traditionally higher. Both Southern and Northern Cote d'Ivoire also received increases in cattle traded from the Sahelian countries (30% and 54% for the south and north, respectively), which suggests that a substantial percentage of local cattle in Cote d'Ivoire were replaced by cheaper imports of Sahelian cattle.

Beef consumption as well as beef prices in both Southern Ghana and Southern Cote d'Ivoire remained the same, as the increase in cattle imports into both zones substituted for decreased beef imports. Beef imports from the rest of the world to Ghana declined by 12% from 19,123 mt to 16,820 mt; and those to Cote d'Ivoire declined by 5% from 16,768 mt to 15,850 mt. This suggests that more open trade in cattle in the sub-region will improve the competitiveness of Sahelian cattle in the coastal markets.