Grain Distribution in Ghana under Imperfectly Competitive Market Conditions

By

Langyintuo, Augustine S.

Contributed Paper presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23, 2010.

Grain Distribution in Ghana under Imperfectly Competitive Market Conditions

Augustine S. Langyintuo[1]

Alliance for a Green Revolution in Africa (AGRA), Eden Square, Block 1, 5th Floor
P O Box 66773, 00800 Westlands, Nairobi, KENYA

[1] Corresponding author:
Dr. Augustine S. Langyintuo
Tel: + 254 20 3675 309
Fax: + 254 20 3675 269
E-mail: Alangyintuo@agra-alliance.org

Abstract

Interspatial and intertemporal grain distribution in Ghana is a private sector activity carried out mainly by traders. These traders sometimes collude to maximize their joint profits. By so doing they influence the conduct of the grains market. To examine the effect of their actions on the informal maize market in Ghana, a spatial equilibrium model was estimated under three scenarios: (1) Perfect competition, (2) Cournot-Narsh conjectures, and (3) Collusion. The results indicate that imperfect competition distorts grain flows, reduces consumer welfare and depresses traders' sales revenue. Collusive behavior of traders, on the other hand, causes the greatest distortion of grain flows as well as trader and consumer welfare. These results draw attention to policy makers and development agents to educate traders against using their associations to foster collusion.

JEL Classification: D4, L1.

Keywords: Spatial equilibrium, monopoly, imperfect competition, interspatial, Cournot-Narsh conjectures

Grain Distribution in Ghana under Imperfectly Competitive Market Conditions

Introduction

Grain marketing in Ghana takes place in the formal and informal market places. At the rural level farmers sell their produce to local assemblers. These assemblers intend sell to wholesalers directly or through commission agents at a fee. Wholesale traders hold large stocks of grains in the urban centers for extended periods of time before releasing them to retailers who eventually sell directly to consumers. It has been observed that urban wholesalers who also retail directly or indirectly through agents constitute over 90% of retailers (Langyintuo, 1997). Some wholesalers also assemble grains in the rural areas.

Unlike the assemblers and commission agents who act individually, wholesale traders in some urban centers organize themselves into associations around commodity groups (eg, yam and cassava sellers association, grain sellers association, etc) under the leadership of so called “market queens” with an objective to agitate for favorable market conditions. The associations sometimes influence the conduct of the market by controlling the quantity of grains released from storage on to the market on any given day. For instance, if the association members anticipate large volumes of grains coming from non-members they deliberately cut back on the quantity of grains they release from their storage. The maize market can therefore be characterized as imperfectly competitive. Where traders are successful in forming an association, they have the power to collude to maximize their joint profits. Where no such association is effective, the traders may make strategic moves to maximize their individual profits.

Using a spatial price equilibrium model incorporating conjectural variations, this paper attempts to analyze the impact of the actions of market traders on maize flows, consumer welfare and maize traders' revenues in a Ghanaian market context. The relevance of the paper is that it operationalizes spatial equilibrium models in a developing country context where marketing is largely influenced by the informal sector. The paper, therefore, hopes to add to the growing literature on spatial equilibrium models.

Spatial Equilibrium Models

Spatial equilibrium models were developed by Enke (1951) and Samuelson (1952) and then refined by Takayama and Judge (1971). They originally assumed that markets are either perfectly competitive or monopolistic. For instance Takayama and Judge (1971), McCarl and Spreen (1980) and Norton and Schiefer (1980) discussed perfect competition and monopoly in spatial market situations. Florian and Los (1982) created a more general formulation of the static single commodity Samuelson, Takayama-Judge model, using a wide class of non-linear programming algorithms. These formulations incorporate transportation networks, such as terminals, ports, and truck routes, and can also be extended to incorporate multiple commodities with non-linear transportation costs (Weinberg, 1985; Batterham and MaCaulay, 1994; Dennis, 1999).

Nelson and McCarl (1984) presented methodological modifications to the traditional imperfectly competitive markets for application in spatial equilibrium models. Subsequently various scientists (Hashimoto, 1985; Weskamp, 1985; Salant, 1986; Capozza and Van Order, 1989; Anderson and Neven, 1990; Sheppard et al, 1992) explored the benefits of incorporating imperfect competition in spatial models.

Spatial equilibrium models are also regularly used to investigate international trade of agricultural commodities. As indicated by Tomek and Robinson (1990), spatial price equilibrium models provide a convenient framework that can be used to determine the indirect as well as the direct effects of changes in production in one or more regions on the volume and direction of trade. In addition, such an analytical model may be used to ascertain the price effects of relaxing or increasing trade barriers between countries or regions. Mwanaumo et al (1997) analysed recent and proposed maize marketing reforms in Zambia. A continuous-space model is used to capture the effects of changing transport systems in place of the traditional point-representation model. This method permits the authors to use pre-reform data on supply, demand, and transport costs to infer both intra- and interregional effects of liberalization and shows that the welfare gains from liberalization are larger than commonly thought. Langyintuo et al (2005) used a spatial and temporal price equilibrium model formulated as a four-period mixed complementary programming to examine the implications of reduction in non-tariff barriers and interest rates on capital on cowpea trade between the Economic Community of West African States (ECOWAS) and Central African Economic and Monetary Cooperation (CAEMC). They showed that with a reduction in real interest rates within ECOWAS, the larger of the two monetary unions, consumers in the relatively larger coastal economies and producers in the smaller Sahelian economies would benefit while all others lose although net social welfare would increase. Removing NTBs among countries in the larger trading bloc may alter the pattern of cowpea flows with total trade volume increasing but inter-bloc trade would decrease. Kawaguchi et al (1997) examined imperfectly competitive spatial equilibrium model for milk market in Japan. They introduced conjectural variation in the standard spatial model to account for various degrees of market imperfection.

Model Formulation

This paper adapts the model by Kawaguchi et al (1997), which introduces conjectural variation in the standard spatial model to account for various degrees of market imperfection. The model is estimated under the assumptions of perfect competition, Cournot-Narsh equilibrium and collusion. The perfect competition scenario considers the situation where traders have no market power to influence price. The situation where traders have conjectures regarding their fellow traders when they take an action such as when no active traders' association is captured in the Cournot-Narsh conjectures scenario. Under the collusion scenario, it is assumed that there is an active and effective traders association through which traders can effectively collude to maximize their joint profits. Other underlying assumptions of the model are that maize traded is homogeneous, market demand functions are linear and traders have equal and constant per unit costs. All maize consumers are price takers.

Let's consider *n* maize producing and *m* consuming regions where there is one grain market in region *j*. Let the unit transportation charge from producing region *i* to consuming region *j* be T_{ij} and assumed to be same for all traders. Traders ship the grain to the various regions with the objective of maximizing their sales revenue less costs of procurement and transportation. Before proceeding with the analysis we need to define the following terms:

M_j = Excess demand of maize demanded in region j, $j = 1, 2, \ldots m$

$M_j = \alpha_j - \beta_j P_j$ = Demand function of maize, and P_j the demand price,

X_i = Excess supply of maize from region i, $i = 1, 2, \ldots n$.

$X_i = v_i + \eta P_i$ = Marginal cost function of producers,

P_i = Producer price in region i,

mr_i = Marginal revenue net of transportation costs for each market,

X_{ij} = Quantity of maize shipped from region *i* to consuming region *j*,

T_{ij} = Unit transportation cost of shipping from region *i* to consuming region *j*, and

R_j = Total maize sales revenue net of transportation costs in consuming region *j*.

Trader *i*'s maize sales revenue net of transportation costs can be expressed as:

$$Max\, R_j = \sum_{j=1}^{m} P_j X_{ij} - \sum_{j=1}^{m} T_{ij} X_{ij} \quad \ldots (1)$$

And for all *n* Traders

$$Max \sum_{j=1}^{m} R_j \quad \ldots (2)$$

Trader *i*'s maize sales revenue in market *j*, (P_jX_{ij}), can be written as:

$$P_j X_{ij} = [\alpha_j / \beta_j - 1/\beta_j\, M_j] X_{ij} \quad \ldots (3)$$

$$= [\alpha_j / \beta_j - (1/\beta_j)(\sum_{j=1}^{m} X_i)] X_{ij}$$

$$= [\alpha_j / \beta_j - (1/\beta_j)(\sum_{k \neq i}^{m} X_{kj} + X_{ij})] X_{ij}$$

Where $k \neq i$ indicates all traders other than *i*. By introducing imperfect competition as adopted by Kawaguchi et al (1997), when trader *i* believes that a change in her maize supply will cause changes in all other traders' maize supply to market *i*, trader *i's* "perceived" marginal maize in market *j* is

$$\partial P_j X_{ij} / \partial X_{ij} = [\alpha_j / \beta_j - 1/\beta_j\, M_j] - (1/\beta_j)(\partial \sum_{kj \neq i} X_{kj} / \partial X_{ij} + 1) X_{ij}$$

$$= P_j - (1/\beta_j)(\theta_{ij} + 1) X_{ij} \quad \ldots (4)$$

Where θ_{ij} is trader *i*'s conjectural variation regarding changes in all other traders' maize supply to market *j* caused by a change in trader *i*'s supply. Using the above relationship, the total revenue maximization problem for all *m* traders can be re-specified as below, net social pay-off maximization adjusted for imperfectly competitive markets.

$$Max\, R_j = \sum_{j=1}^{m} \int [(\alpha_j / \beta_j) - (1/\beta_j) M_j] dM_j - \sum_{j=1}^{m} (1/\beta_j)(\theta_{ij} + 1) \int X_{ij} dX_{ij} - \sum_{j=1}^{m} T_{ij} \qquad \ldots (5)$$

subject to:

$$M_j \leq \sum_{j=1}^{m} X_{ij} \text{ for all } j \qquad \ldots (6)$$

$$\sum_{i=1}^{n} X_{ij} \leq X_i \text{ for all } i \qquad \ldots (7)$$

$$M_j \geq 0, \quad X_{ij} \geq 0.$$

When the market is perfectly competitive θ_{ij} = -1 and the $\sum (1/\beta j)(\theta_{ij} + 1) \int X_{ij} dX_{ij}$ term drops out. But when Cournot-Narsh behavior is assumed, $\theta_{ij} = 0$ meaning that Trader *i* believes that other traders will not change their supply in response to the trader's action. In the case of a collusion, θ_{ij} = 1.

Using the Lagrange function (*L*) with the multipliers λ and ψ for constraints (5) and (6), respectively, the Kuhn-Tucker optimality conditions for the maximization problem can be expressed as follows:

$$\partial L / \partial Mj = \alpha_j / \beta_j - (1/\beta_j) M_j - \lambda_j \leq 0 \qquad \ldots (8)$$

$$M_j (\partial L / \partial Mj) = 0 \text{ for all } j$$

$$\partial L / \partial X_{ij} = -(1/\beta_j)(\theta_{ij} + 1) X_{ij} - T_j + \lambda_j - \psi \leq 0 \qquad \ldots (9)$$

$$X_{ij} (\partial L / \partial X_{ij}) = 0 \text{ for all } i \text{ and } j$$

$$-\partial L / \partial \lambda_j = M_j - \sum_{i-1}^{m} X_{ij} \leq 0 \qquad \ldots (10)$$

$$\lambda_j (\partial L / \partial \lambda) = 0 \text{ for all } j$$

$$-\partial L/\partial \Psi_i = \sum_{j=1}^{m} X_{ij} - S_i \quad \ldots (11)$$

$$\Psi_i (L/\partial \Psi) = 0$$

The Lagrange multipliers λ and ψ measure maize demand price and the marginal revenue net of transportation cost for each market. The above Kuhn-Turker conditions indicate that each trader must equalize marginal revenue net of transportation costs across all markets where it sells maize. The $(1/\beta_j)(\theta_{ij}+1)X_{ij}$ in equation (8) indicates the difference between maize demand price and trader *i*'s marginal revenue in market *j*. To complete the model we introduce producers' supply functions for maize. Producers operate under perfect competition conditions and are therefore price takers. Subject to prevailing producer prices, producers in region *i* choose a level of output at which marginal cost equal to price.

$$P_i = R_j / X_i \quad \ldots (12)$$

$$X_i = v_i + \eta_i P_i \quad \ldots (13)$$

To solve the model, a mathematical programming model using General Algebraic Modeling System (GAMS) was employed in an iterative mode. First, the equilibrium demand quantities and prices according to equations (3) and (11) are estimated based on initial values of X_i and given patterns of behavior of the traders. The second iteration involves the estimation of producer price based on equation (12). In the third iteration, new values of X_i for the next iteration are computed based on the calculated producer price and marginal cost function of producing regions under the assumption that producers are price takers in equation (13). This procedure is repeated until values for X_i become stationery.

Data and empirical results

The regional maize supplies as well as producer and consumer prices between 2006 and 2008 (Table 1) were obtained from the Policy Planning, Monitoring and Evaluation Division of the Ghana Ministry of Food and Agriculture (PPMED, 2008). Prices in from 2006 and June 2007 were denominated[2]. The per capita consumption of maize and regional population data from GSS (2008) were used to estimate regional maize demands. Together with supply, excess supply and demand by region were established as in Figure 1. Eastern, Ashanti, Northern and Brong-Ahafo Regions are net exporters while Central, Western, Greater Accra, Upper East and Upper West Regions are net importers of maize. (Volta region was not included in the analysis for data inadequacy.) Supply and demand elasticities were extracted from the Ghana Living Standard Survey reports for 2008 and assumed to be the same for all locations. Distances between producing and consuming centers ranged from 120 km for Eastern region – Greater Accra region route and 864 km for the Northern region – Western region route. Average transportation charge was estimated at GH¢0.01 per ton of maize per kilometer in 2008 nominal prices.

The estimated results indicate that under the perfect competition scenario, the optimal quantity of maize shipped out to consuming regions is 356,558.577 mt (Table 2). Northern region supplies Upper East, and Upper West regions. All the supply from Ashanti gets shipped to Greater Accra and all the demand for Central region is satisfied by maize from Eastern region. Eastern, Brong Ahafo and Ashanti regions service greater Accra with the highest average price for maize.

[2] In July 2007 the Ghana government re-denominated its currency by setting ten thousand cedis (¢) to one Ghana Cedi (GH¢). Exchange rate as at the end of May, 2010 was: 1US$ = GH¢1.45

The introduction of imperfect competition results in differences in maize allocation to consuming regions. Under the Cournot Nash equilibrium, maize is shipped to all consuming regions but the total quantity shipped is about 8% less than in the case of perfect competition (Tables 3). Greater Accra and Upper East regions suffer the most reduction in supplies. The introduction of monopoly power further restricts grain shipment to the various locations. Table 4 indicates that monopoly conditions lead to up to 16%, about twice the proportion reduction in grains supplied compared with perfect competition. Under monopoly, the reduction of up to 21% in the supply to Accra is substantially higher than for the Upper East with up to 17% reduction. The Upper West is the least affected.

Reduction in sales quantities reflects in relatively higher demand prices at equilibrium. The highest demand price for maize was observed in Accra. Under imperfect competition, consumers in Upper East region experience 21% increase in price, higher than any other location. Under monopoly situation, price increase is much more significant in the Greater Accra region with 31% over the perfect competition situation than observed in any other location. The Upper West region experienced the least increase in price just as the case for quantity restriction.

Despite the increase in prices, reduction in quantity has resulted in reduction in total revenue accrued to the traders contrary to their objective. This is in line with economic principle given that maize a is price inelastic commodity. The total sales revenue of ¢16.2 million under perfect competition is reduced by 10% under imperfect competition and by 17% under monopoly.

Conclusion

The introduction of imperfect competition in spatial markets greatly affects maize flow. Trade quantities are restrict with imperfection with the greatest restriction in the case of monopoly. These restrictions resulted in increased prices. However, total sales revenues are decreased as a result of the quantity restriction. Therefore, imperfect conditions for a price inelastic commodity such as maize do not increase the general welfare of traders contrary to their expectations. At the same time, they reduce demand given the relatively high prices and thus decrease consumers' welfare. Therefore imperfect competition in the maize market in Ghana distorts trade flows and leads to a general welfare loss for both consumers and traders. This study draws attention to the fact that collusive behaviors are unlikely to result in increased profits when the commodity is price inelastic. The need for policy makers and development agents to educate traders against using their associations to foster collusion is imperative for the general welfare of consumers and traders alike.

References

Anderson, S.P. and Neven, D. J., 1990. Spatial Competition a la Cournot: Price Discrimination by Quantity-Setting Oligopolists. Journal of Regional Science 30 (1), 1-14.

Batterham, R.L., MaCaulay T.G., 1994. Price-linked Farm and Spatial Equilibrium Models. Australian Journal of Agricultural Economics 38 (2), 143-170.

Capozza, D.R., and Van-Order, R., 1989. Spatial Competition with Consistent Conjectures. Journal of Regional Science 29 (1), 1-13.

Dennis, S. M., 1999. Using Spatial Equilibrium Models to Analyze Transportation Rates: An Application to Steam Coal in the United States. Transportation Research. Part e, Logistics & Transportation Review, Exerter 35 (3), 145-154.

Enke, S., 1951. Equilibrium Among Spatially Separated Markets: Solution by Electric Analogue. Econometrica 19, 40-47.

Florian, M. and Los, M., 1982. A New Look at static Spatial Price Equilibrium Models. Regional Science and Urban Economics; Amsterdam 12 (4), 579-598.

GSS, 2008. Ghana Living Standards Survey: Report on the Third Round (GLSS 3). Ghana Statistical Service, Accra, Ghana.

Hashimoto, H., 1985. A Spatial Nash Equilibrium Model, in: Harer, P.T., (Eds), Spatial Price Equilibrium: Advances in theory, computation and Application. New York; Springer-Verlag, pp. 20 – 40.

Kawaguchi, T., Suzuki, N., and Kaiser, H.M., 1997. A Spatial Equilibrium Model for Imperfectly Competititve Milk Markets. American Journal of Agricultural Economics. 79, 851-859.

Langyintuo, A. S., 1997. Analysis of maize marketing system in Northern Ghana, in: Badu-Appraku, B., Fakorede, M.A.B., Ouedraogo, M., and Quin, F.M. (Eds), Strategy for sustainable maize production in West and Central Africa: Proceedings of a Regional Workshop 21 – 25 April.1997, IITA-Cotonou, Benin Republic. IITA, pp 388-401.

Langyintuo, A. S., Lowenberg-DeBoer, J., and C. Arndt. 2005. Potential Impacts of the Proposed West African Monetary Zone on Cowpea Trade in West and Central Africa. Agricultural Economics. 33, supplement, 411-421.

McCarl, B.A., and Spreen, T. H., 1980. Price Endogenous Mathematical Programming as a Tool for Sector Analysis. American Journal of Agricultural Economics 62, 21-48.

Mwanaumo, A., Masters, W. A. and Prekel, P. V., 1997. A Spatial Analysis of Maize Marketing Policy Reforms in Zambia. American Journal of agricultural Economics ; 79 (2), 514-23.

Nelson, C. H., and McCarl, B. A., 1984. Including Imperfect Competition in Spatial Equilibrium Models. Canadian Journal of Agricultural economics, 55-70.

Norton, R. D., and Schiefer, G. W., 1980. Agricultural Sector Programming Models: A review. European Review of Agricultural Economics, 229-64.

PPMED, 2008. Policy Planning, Monitoring and Evaluation Division of the Ministry of Food and Agriculture of Ghana, Estimates of production of selected crops in Ghana. Ministry of Agriculture, Accra, Ghana.

Salant, D. J., 1986. Equilibrium in a Spatial Model of Imperfect Competition with Sequential Choice of Locations and Quantities. The Canadian Journal of Economics; Toronto 19 (4), 685-717.

Samuelson, P. A., 1952. Spatial Price Equilibrium and Linear Programming. American Economic Review 42 , 283-303.

Sheppard, E., Haining, R. P. and Plummer, P., 1992. Spatial Pricing in Interdependent Markets. Journal of Regional Science 32 (1), 55-75.

Takayama, T., and Judge, G., 1974. Spatial and Temporal Price and Allocation Models. Amsterdam: North-Holland.

Tomek, W.G. and Robinson, K. L. 1990. Agricultural Product Prices, Third Edition. Cornell University Press, Ithaca.

Weinberg, J., 1985. Betrand Oligopoly in a spatial Context: The Case of Quantity Independent Transportation Costs. Regional Science and Urban Economics; Amsterdam, 263-276.

Weskamp, A., 1985. Existence of Spatial Cournot Equilibria. Regional Science and Urban Economics; Amsterdam; 15 (2), 219-228.

Table 1: Net supply of, demand for and supply/demand elasticities for maize by region (2006-08)

	Supply		Demand		Supply/ demand Elasticity[2]
	Quantity (mt)	Price (¢/mt)[1]	Quantity (mt)	Price (¢/mt)[1]	
Northern	82,650	35.33	-	-	0.42
Ashanti	28,000	49.38	-	-	0.42
Brong Ahafo	90,860	40.41	-	-	0.42
Eastern	57,290	42.45	-	-	0.42
Upper East	-	-	42,700	41.88	-0.5
Upper West	-	-	28,480	38.75	-0.5
Greater Accra	-	-	80,460	52.99	-0.5
Western	-	-	44,100	52.51	-0.5
Central	-	-	54,200	47.26	-0.5
Total/average	258,800	41.90	249,940	46.65	-0.5

Sources: PPMED, MoFA, 2008

Note: [1] Exchange rate at end May, 2010: 1 US$ = GH¢1.45

[2] Elasticities assumed similar for all regions in same category

Table 2: Spatial perfect competition equilibrium quantities of maize shipped to consuming regions from supply regions (ton)

	Consuming region					Total
	Upper East	Upper West	Greater Accra	Western	Central	
Northern	43,690	27,479	-	14,429	-	85,598
Ashanti	-	-	26,273	-	-	26,273
Brong-Ahafo	-	-	2,646	32,752	55,877	91,275
Eastern	-	-	57,733	-	-	57,733
Total	43,690	27,479	86,653	47,180	55,877	260,879

Note: - No value

Table 3: Spatial imperfect competition equilibrium quantities of maize shipped to consuming regions from supply regions (ton)

	Consuming region					Total
	Upper East	Upper West	Greater Accra	Western	Central	
Northern	15,745	10,724	23,567	13,253	15,511	78,800
Ashanti	3,503	2,412	7,226	4,712	5,268	23,122
Brong-Ahafo	13,334	9,008	25,695	15,745	17,953	81,735
Eastern	6,464	3,867	17,177	10,711	12,036	50,253
Total	39,046	26,011	73,664	44,421	50,768	233,910
% of PC	-12	-6	-18	-6	-10	-12

Table 4: Spatial monopoly equilibrium quantities of maize shipped to consuming regions from supply regions (ton)

	Consuming region					Total
	Upper East	Upper West	Greater Accra	Western	Central	
Northern	13,590	9,435	21,211	13,208	14,876	72,318
Ashanti	3,425	2,481	6,185	4,238	4,647	20,976
Brong-Ahafo	12,590	8,847	22,337	14,626	16,248	74,648
Eastern	6,872	4,625	14,369	9,494	10,468	45,829
Total	36,477	25,388	64,102	41,566	46,239	213,772
% over PC	-20	-8	-35	-14	-21	-22
% over IPC	-7	-2	-15	-7	-10	-9

Table 6: Equilibrium prices under different market conditions (GH¢/ton)

	Consuming region				
	Upper East	Upper West	Greater Accra	Western	Central
Perfect competition	40.00	41.62	45.69	45.88	44.46
Imperfect competition	50.08	46.46	63.22	51.75	53.86
% of PC	125	112	138	113	121
Monopoly	57.38	48.76	83.48	59.11	64.93
% of PC	143	117	183	129	146

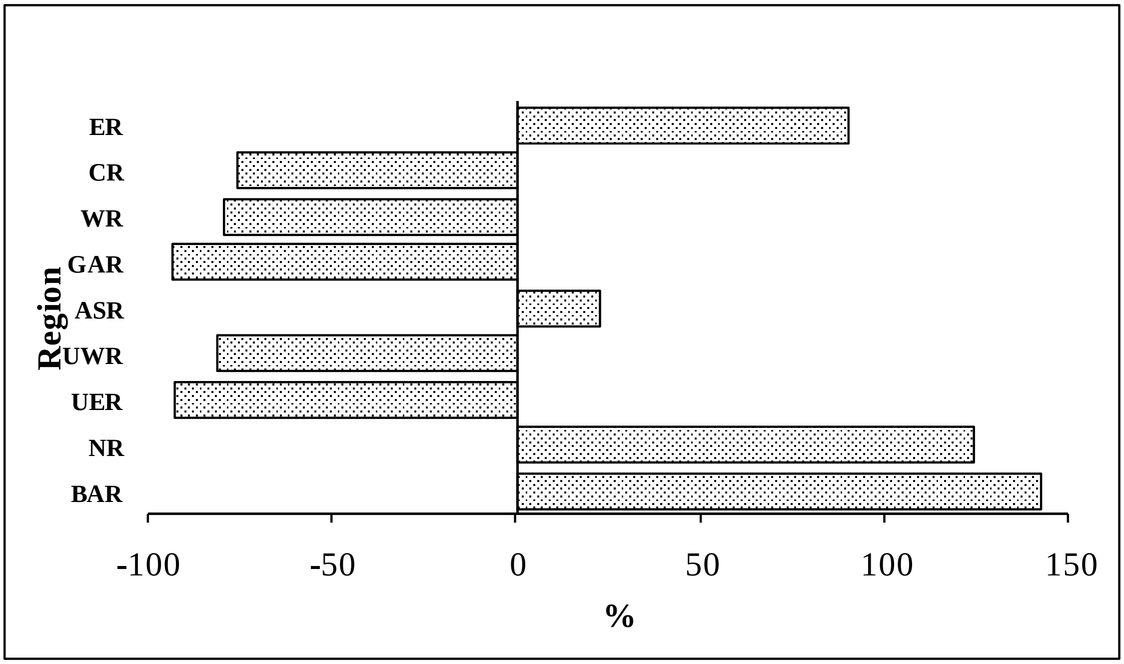

Figure 1: Maize supply as a percentage of demand by region in Ghana, 2006-08

Key:			
	ER	=	Eastern Region
	CR	=	Central Region
	WR	=	Western Region
	GAR	=	Greater Accra Region
	ASR	=	Ashanti Region
	UWR	=	Upper West Region
	UER	=	Upper East Region
	NR	=	Northern Region
	BAR	=	Brong Ahafo Region