Grain Distribution in Ghana under Imperfectly Competitive Market Conditions

By

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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
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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).


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:

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

$M_j = \alpha_j - \beta_jP_j = \text{Demand function of maize, and } P_j \text{ the demand price}$

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

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

$P_i = \text{Producer price in region } i,$
\(mr_i = \) 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:

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

And for all \(n\) Traders

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

Trader \(i\)’s maize sales revenue in market \(j\), \((P_j X_{ij})\), can be written as:

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

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

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

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

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

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

Where \(\theta_{ij}\) 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.

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

subject to:

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

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

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

When the market is perfectly competitive $\theta_{ij} = -1$ and the $\sum_{j=1}^{m} (\gamma_{ij} / \beta_j) (\theta_{ij} + 1) \int X_{ij} dX_{ij}$ term drops out. But when Cournot-Nash 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, $\theta_{ij} = 1$.

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

$$
\frac{\partial L}{\partial M_j} = \frac{\alpha_j}{\beta_j} - \frac{1}{\beta_j} M_j - \lambda_j \leq 0 \quad \ldots \quad (8)
$$

$$
M_j \left( \frac{\partial L}{\partial M_j} \right) = 0 \text{ for all } j
$$

$$
\frac{\partial L}{\partial X_{ij}} = -\left( \frac{1}{\beta_j} \right) (\theta_{ij} + 1) X_{ij} - T_{ij} + \lambda_j - \psi \leq 0 \quad \ldots \quad (9)
$$

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

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

$$
\lambda_j \left( \frac{\partial L}{\partial \lambda} \right) = 0 \text{ for all } j
$$
\[-\frac{\partial L}{\partial \psi_i} = \sum_{j=1}^{m} X_{ij} - S_i \quad \ldots (11)\]

\[\psi_i(L/\partial \psi) = 0\]

The Lagrange multipliers \(\lambda\) and \(\psi\) 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 \((1/\beta_j)(\theta_j + 1)X_{ij}\) 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.

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\(^2\) 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


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

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

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)

<table>
<thead>
<tr>
<th>Consuming region</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper East</td>
</tr>
<tr>
<td>Northern</td>
<td>43,690</td>
</tr>
<tr>
<td>Ashanti</td>
<td>-</td>
</tr>
<tr>
<td>Brong-Ahafo</td>
<td>-</td>
</tr>
<tr>
<td>Eastern</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>43,690</td>
</tr>
</tbody>
</table>

Note: - No value
Table 3: Spatial imperfect competition equilibrium quantities of maize shipped to consuming regions from supply regions (ton)

<table>
<thead>
<tr>
<th>Consuming region</th>
<th>Upper East</th>
<th>Upper West</th>
<th>Greater Accra</th>
<th>Western</th>
<th>Central</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>15,745</td>
<td>10,724</td>
<td>23,567</td>
<td>13,253</td>
<td>15,511</td>
<td>78,800</td>
</tr>
<tr>
<td>Ashanti</td>
<td>3,503</td>
<td>2,412</td>
<td>7,226</td>
<td>4,712</td>
<td>5,268</td>
<td>23,122</td>
</tr>
<tr>
<td>Brong-Ahafo</td>
<td>13,334</td>
<td>9,008</td>
<td>25,695</td>
<td>15,745</td>
<td>17,953</td>
<td>81,735</td>
</tr>
<tr>
<td>Eastern</td>
<td>6,464</td>
<td>3,867</td>
<td>17,177</td>
<td>10,711</td>
<td>12,036</td>
<td>50,253</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>39,046</strong></td>
<td><strong>26,011</strong></td>
<td><strong>73,664</strong></td>
<td><strong>44,421</strong></td>
<td><strong>50,768</strong></td>
<td><strong>233,910</strong></td>
</tr>
<tr>
<td>% of PC</td>
<td>-12</td>
<td>-6</td>
<td>-18</td>
<td>-6</td>
<td>-10</td>
<td>-12</td>
</tr>
</tbody>
</table>
Table 4: Spatial monopoly equilibrium quantities of maize shipped to consuming regions from supply regions (ton)

<table>
<thead>
<tr>
<th>Consuming region</th>
<th>Upper East</th>
<th>Upper West</th>
<th>Greater Accra</th>
<th>Western</th>
<th>Central</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>13,590</td>
<td>9,435</td>
<td>21,211</td>
<td>13,208</td>
<td>14,876</td>
<td>72,318</td>
</tr>
<tr>
<td>Ashanti</td>
<td>3,425</td>
<td>2,481</td>
<td>6,185</td>
<td>4,238</td>
<td>4,647</td>
<td>20,976</td>
</tr>
<tr>
<td>Brong-Ahafo</td>
<td>12,590</td>
<td>8,847</td>
<td>22,337</td>
<td>14,626</td>
<td>16,248</td>
<td>74,648</td>
</tr>
<tr>
<td>Eastern</td>
<td>6,872</td>
<td>4,625</td>
<td>14,369</td>
<td>9,494</td>
<td>10,468</td>
<td>45,829</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>36,477</strong></td>
<td><strong>25,388</strong></td>
<td><strong>64,102</strong></td>
<td><strong>41,566</strong></td>
<td><strong>46,239</strong></td>
<td><strong>213,772</strong></td>
</tr>
<tr>
<td>% over PC</td>
<td>-20</td>
<td>-8</td>
<td>-35</td>
<td>-14</td>
<td>-21</td>
<td>-22</td>
</tr>
<tr>
<td>% over IPC</td>
<td>-7</td>
<td>-2</td>
<td>-15</td>
<td>-7</td>
<td>-10</td>
<td>-9</td>
</tr>
</tbody>
</table>
Table 6: Equilibrium prices under different market conditions (GHe/ton)

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