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Modeling the Effects of Oligopolistic Behaviour of Mobile Telecommunication Network (MTN) and Tigo in the Telecommunication Market: The Ghanaian Experience

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Abstract

Telecommunication industry in Ghana was liberalized in 1994 and this has prompted a lot of telecommunication companies to compete in the small market in Ghana. The two dominant firms are MTN and Tigo that have captured about 80% of the subscription base in the telecommunication market in Ghana. The tendency for these two dominant firms to establish a Nash Equilibrium where it is possible for them to reduce output and increase price in order to maximize profit is very high and the study follows this using their reaction functions and calculus approaches. The study considered the oligopolistic behavior of the two dominant firms using the Cournot duopoly model with emphasis on the reaction functions and calculus to establish their equilibrium. The residual demand of each firm was estimated to help in the graphical illustration of the Cournot duopoly equilibrium. The mathematical version of the equilibrium model was derived using calculus. Data for the work included document, archival records and interviews from the telecommunication companies. Using the reaction functions and the calculus approaches, the results indicate that the profit maximizing values of MTN and Tigo will lead to establishing Nash Equilibrium output levels. The potential theoretical implications are that, recognizing their mutual interdependence, the two firms are likely to agree to act in unison in order to maximize total profit in the industry. Both firms will do that by using self-imposing strategies to reduce output, raise the price and increase their profit.

Keywords: cournot duopoly, residual demand, optimum output, reaction functions, nash equilibrium

INTRODUCTION

Ghana is one of the first African countries to introduce widespread liberalization in basic telecommunication services. In August, 1994, Ghana took an important step in embracing the potential of competitive markets to generate growth and innovation in the sector. Mobile phone communication was not an integral part of Ghanaian communication system until the liberalization of the sector in 1995. Prior to this, the Post/Telecommunication Services monopolized the provision of communication services within Ghana and between Ghana and the outside world.

Today, Ghana operates a fairly opened telecommunication industry, having privatized some institutions, and encouraged both private domestic and foreign investors to participate in the industry. This is done within the framework of macroeconomic reforms and liberalization. Much of the intellectual foundations of Ghana's telecommunication reforms can be traced to a World Bank publication (Mustafa et al 1997) on telecommunication reforms in the sub-Sahara Africa. World Bank country report for Ghana argues for the separation of "Post" and "Telecommunication" saying that when telecommunication stands alone, it will be better placed to attract private sector capital and management (Mustafa et al 1997:20). As part of the process of creating the duopoly in the telecommunication sector, the Ghana government in 1996 announced the offer for sale of a Second Operator License (SNO License) for the provision both domestic and international telecommunication services (Telecommunications in Ghana, 1996). Services and products provided by the players in the telecommunication sector include fixed and mobile phone, data and internet services, and public prepaid telephones among others.

Market Structure, Liberalization and Competition

The development of the telecommunication industry over the past decades has yielded a wide array of significant changes in the economy of Ghana. Among the most important changes has been the transformation of the domestic telecommunication industry from a largely monopolized state-owned model to a broadly competitive, private and open market model. Ghana has been among the leading

countries in Africa in promoting these developments (Ministry of Communications: National Telecommunication Policy, 2005).

The traditional market structure for telecommunication in Ghana is evolving with changes to allow for robust and flexible development of new services, marketing options and customer choices. The table below shows the progress made in the provision of phones from 1994 to 2001. The year 1997 marked the beginning of Telecom Malaysia's takeover of Ghana Telecom Management for a contract period of 5 years.

Table 1: Progress in the Provision of Phone from 1994-2001

Year	1994	1995	1996	1997	1998	1999	2000	2001
Fixed Phones	50,007	63, 067	77, 886	100, 932	133,396	158, 398	201, 148	242, 122
Percentage Growth				29.59	32.2	18.7	27	20.2
Pay Phones	26	30	453	500	1,815	3,044	3,180	4,321
Percentage Growth				10.4	26.3	67.7	44.7	35.9
Phone per 100	0.3	0.37	0.44	0.57	0.72	0.81	1.09	1.31

Source: Marketing Department, Ghana Telecom & The Ministry of Communications-2001

The Share of MTN and Tigo in the Telecommunication Market in Ghana

The study identifies that there are few firms facing the emerging telecommunication market in Ghana. The establishment of Mobile Telecommunication Network (MTN) in the telecom market in Ghana dates back to 1993 when it started as Spacefon. The name changed to Areeba when the Lebanese-owned Investcom purchased shares in the company. MTN acquired Investcom in July 2006 and after nearly a year of the takeover process in 2007, the company re-branded as MTN.

Tigo started in 2002 in Ghana with the company name as Buzz. With its trendy lifestyle image, it has also offered exciting services to numerous Ghanaians.

The study captures the subscription base of mobile telephony operators in Ghana. The total mobile phone subscription in Ghana by August 2008 is 10,242,916. Out of this, the subscription base of MTN was 5,539,065 (54.08%). Tigo had 2,668,316 (26.05%), GT/Vodafone had 1,648,544 (16.09%) while Kasapa had 386,991 (3.78%). [National Communication Authority, August, 2008]. These have been captured in figure 1 below:

The study has become necessary because of the high rate of emerging trends in the telecommunication industry in Ghana. The objective is to make the microeconomic analysis to establish the possibility of MTN and Tigo agreeing to act in unison in order to amximise total profit in the industry.

The section following describes the oligopolistic behavior of MTN and TIGO in the market using the duopoly model. Both MTN and Tigo produce similar products with a larger market share of the Ghanaian economy.

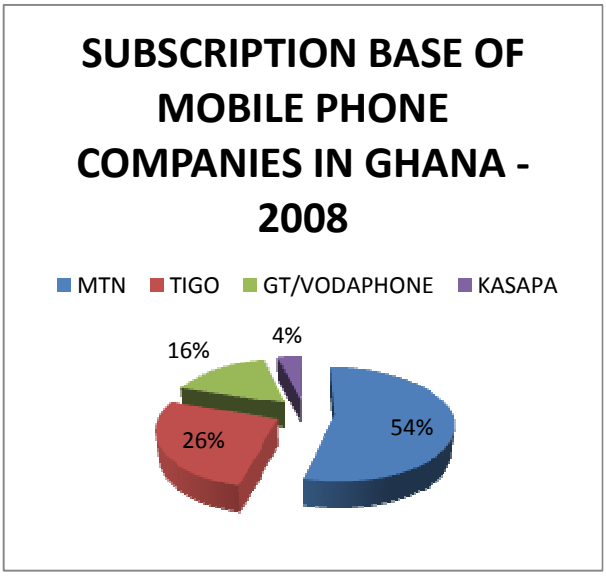

Fig. 1 The Subscription Base of MTN, Tigo, GT/Vodafone and Kasapa in Ghana
Source: National Communication Authority – August, 2008

The Concept of Cournot Duopoly Model

The central focus is on equilibrium in the duopoly game. The model follows the work of Cournot (1838) in that it is characterized by a homogeneous product and pure competition on the buyers' side of the market. The decision variable for each firm is the amount of the homogeneous good to produce.

The study of Bowly (1924) of oligopoly problem has been untimely related to reaction functions of firms. The notion of each firm's belief about its rival's response to change in the firm's output has been captured in the model. This belief enters into the firm's decision process for its output. Frisch (1939) and Friedman (1977) among others have considered dynamic reaction function models in their studies.
We itemize the assumptions in the model as:

1. Two firms namely MTN and Tigo have dominant control in the market
2. The products of these firms are homogeneous
3. The firms have a constant marginal cost, **c**
4. Each firm aims at maximizing profits based on the expectations that its own output decisions will not have effects on the output decisions of its rival
5. Each firm takes the quantity set by its competitor as given, evaluates its residual demand, and behaves as a monopoly.

Mathematical Analysis of the Graphical Cournot Duopoly Equilibrium

In analyzing the model, we consider prices and quantities of MTN and Tigo with constant marginal cost as below:

p_1 = (MTN) price,
p_2 = (Tigo) price,
q_1= (MTN) quantity
q_2 = (Tigo) quantity
c = marginal cost is constant, and identical for both firms

Equilibrium prices of the two firms will be:

$$p_1 = p_2 = P(q_1 + q_2) \quad (1)$$

This implies that MTN's profit is given by $\Pi_1 = q_1 (P(q_1 + q_2) - c)$ (2)

Calculation of Residual Demand

To calculate MTN's residual demand we assume that MTN believes Tigo is producing quantity q_2. We look at MTN's optimal quantity by considering fig 2 below. If MTN decides not to produce anything, then price is given by $P(0 + q_2) = P(q_2)$. If MTN produces q_1' then P (q_1' + q_2) as shown on fig 2 below gives price. More generally, for each quantity that MTN might decide to set, price is given by the curve $d_1(q_2)$. The curve $d_1(q_2)$ is called MTN's residual demand.; it gives all possible combinations of MTN's quantity and price for a given value of q_2.

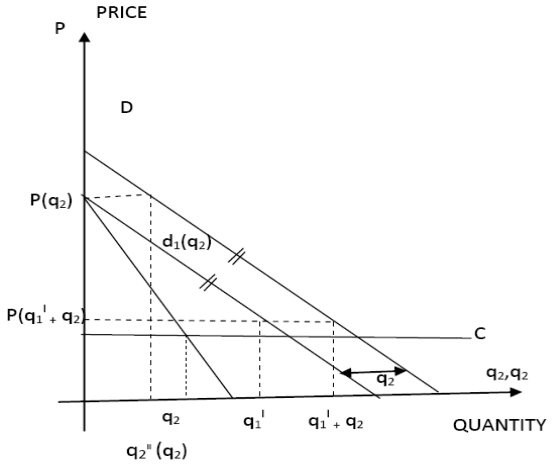

Fig 2: The Optimal Quantity of MTN

MATERIALS AND METHODS

The focus for thinking about the oligopolistic behaviour of MTN and Tigo in the telecommunication industry in Ghana was derived from the work of Cournot (1938) which is characterized, by a homogeneous product and pure competition from the buyers' side of the market. The decision variable for each firm in the model was the amount of the homogeneous good to produce. The reaction functions illustrated by the two firms were modeled after those used by Frisch (1939) and Bowley (1924. These were employed together with differential calculus in determining the Nash Equilibrium output of both MTN and Tigo. To capture how each firm behaves optimally given the other firm's action, an in-depth study was conducted on the telecommunication market in Ghana to solicit for data on the subscription base of the companies, prices of their products, levels of output, and the progress in the provision of phones in the market since 1994. The sources of data included documents, interviews and archival records. Each firm's residual demand was estimated based on the marginal revenue-marginal cost equation with a constant marginal cost. This is based on the assumption that each firm knows the output of its rival. The combine approaches (the reaction functions and the differential calculus) are of theoretical and practical importance because they both underlie the extent to which both firms derive their equilibrium output.

Results of Duopoly Model Optimum Output

In determining MTN's optimum output, we must find where marginal revenue equals marginal cost. Marginal cost (c) is assumed constant. Marginal revenue is a curve - $r_1(q_2)$ – with twice the slope of $d_1(q_2)$ and with the same vertical intercept. The point at which the two curves (c and $r_1(q_2)$ intercept corresponds to quantity q_1"(q_2). MTN's optimum q_1"(q_2), depends on what it believes Tigo is doing. To find equilibrium, we derive MTN's optimum for other possible values of q_2. Fig 3 below considers two possible values of q_2. If q_2 = 0, then the MTN's residual demand is effectively the market demand $d_1(0)$ = D. The optimal solution is for MTN to choose the monopoly quantity; q_1"$(0) = q^m$ (q^m is the monopoly quantity). If Tigo were to choose the quantity corresponding to perfect competition, $q_2 = q^c$ such that $P(q^c) = c$, then MTN's optimum would be to produce nil: q_1"$(q^c) = 0$. This is the point at which marginal cost intercepts the marginal revenue corresponding to $d_1(q^c)$ in fig 3 below.

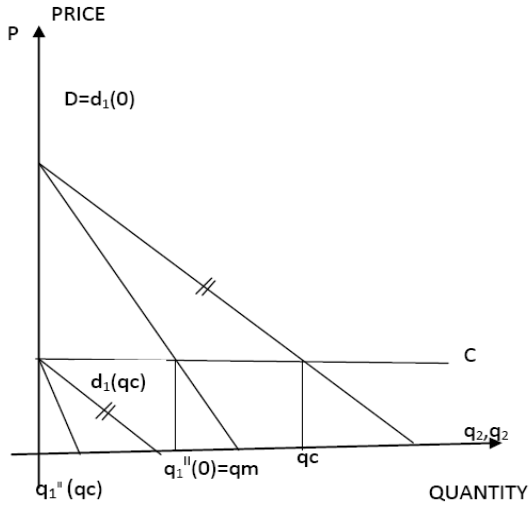

Fig 3: The Equilibrium Point of MTN and Tigo

DISCUSSION OF RESULTS

The reaction function approach is a powerful method of analysis. It expresses the output of each duopolist as a function of its rival's output. It can be shown that, given the linear demand and constant marginal cost, function q_1"(q_2) is also linear. Because we have two points, we can draw the entire function q_1"(q_2) as in fig 4 below. The function q_1"(q_2) is the reaction function of MTN and it gives MTN the optimal choice for each possible choice by Tigo. In other words, it gives MTN's choice given what it believes Tigo is doing. MTN's reaction function is produced in fig 4 below [ie q_1"(q_2)]:

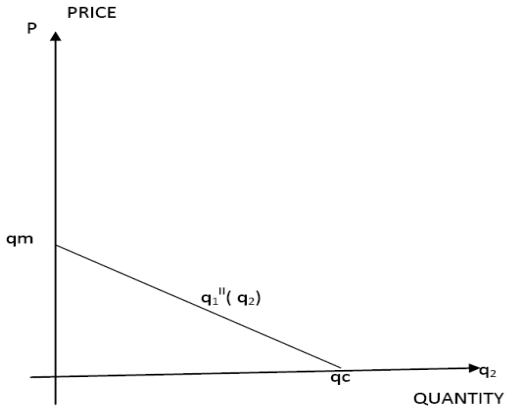

Fig 4 MTN's Reaction Function

The last stage of finding the Cournot equilibrium is to find Tigo's reaction function. In this case it is symmetrical to MTN's as they have the same cost function. MTN's reaction function gives a relationship between its output (q_1) and the output of Tigo (q_2) with the property that for any specified value of Tigo's output (q_2), the corresponding value of MTN's output (q_1) maximizes the company's profits. Tigo's reaction function also gives the value of Tigo's output (q_2) which maximizes profits for Tigo for any specified value of the output of MTN (q_1). An equilibrium solution is the pair of the values of both MTN and Tigo which satisfies both reaction functions. The equilibrium is the intersection point of the reaction curves. See fig 5 below:

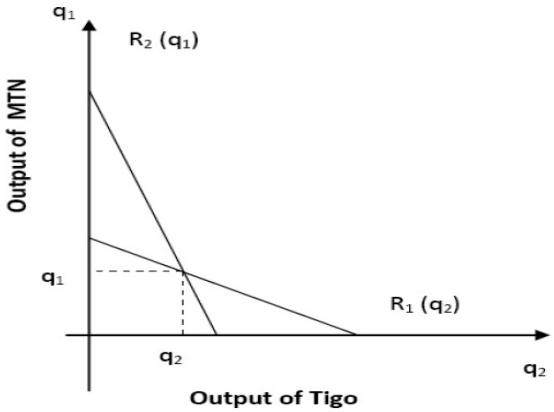

Fig 5: Reaction Functions of MTN and Tigo

The intersection of the reaction curves in the model demonstrates that the firms will choose Nash Equilibrium output levels, which are the result of their reaction curves.

Suggested Approach to Mathematical Version of the Equilibrium Model: Using the Best Responses of MTN and Tigo

In very general terms, the price function for the (duopoly) industry is taken as $P\ (q_1 + q_2)$ and firm I has cost structure $C_i(q_i)$. To calculate the Nash equilibrium, the best response functions of both MTN and Tigo is calculated as illustrated below. The profit of firm I is revenue minus cost. Revenue is the product of price and quantity and cost is given by the firm's cost function, so profit (as described above) is:

$$\Pi_i = (P\ (q_1 + q_2)\ ).\ q_i - C_i(q_i) \quad (3)$$

The best responses to find the value of q_1 that maximizes Π_i given q_j, with $i \neq j$, i.e. given some output of the opponent firm, the output that maximizes profit is found. Hence, the maximum of Π_i with respect to q_1 is to be found. First, taking the derivative of (3) with respect to q_i, we get

$$\frac{\partial \pi}{\partial q_i} = \frac{\partial P(q_1 + q_2)}{\partial q_i} \cdot q_i + P(q_1 + q_2) - \frac{\partial C_i(q_i)}{\partial q_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Setting the appropriate partial derivatives of (4) to zero for maximization gives us:

$$\frac{\partial \pi}{\partial q_i} = \frac{\partial P(q_1 + q_2)}{\partial q_i} \cdot q_i + P(q_1 + q_2) - \frac{\partial C_i(q_i)}{\partial q_i} = 0 \quad (5)$$

The values of q_i that satisfy this equation are the best responses. The Nash equilibrium are where both $q_1 and\ q_2$ are best responses, given those values of $q_1 and\ q_2$.

Analysis of the Nash Equilibrium Model

Suppose the industry has the following price structure:

$$P(q_1 + q_2) = a - (q_1 + q_2) \quad (6)$$

The profit of the firm i $(with\ cost\ structure\ C_i(q_i) such\ that\ \frac{\delta^2 C_i(q_i)}{\partial q_i^2} = 0\ and\ \frac{\partial C_i(q_i)}{\partial q_j} = 0, j \neq i\ for\ ease\ of\ computation)$ is

$$\Pi_i = (a - (q_1 + q_2))\cdot q_i - C_i(q_i) \quad (7)$$

$$\frac{\partial(a-(q_1+q_2))}{\partial q_i}\cdot q_i + a-(q_1+q_2) - \frac{\partial C_i(q_i)}{\partial q_i} = 0 \quad (8)$$

From the general case, we consider the best response function of MTN as:

Without loss of generality, we consider the best response function of MTN as:

$$-q_1 + a - (q_1 + q_2) - \frac{\partial C_1(q_1)}{\partial q_1} = 0 \quad (9)$$

=>

$$=> q_1 = \frac{a - q_2 - \frac{\partial C_1(q_1)}{\partial q_1}}{2} \quad (10)$$

$$(11)$$

By symmetry, the response function of Tigo is:

$$=> \quad q_2 = \frac{a - q_1 - \frac{\partial C_2(q_2)}{\partial q_2}}{2} \quad (12)$$

The values of $q_1 and\ q_2$ [ie equations (11) and (12)] shown above are the best response functions of MTN and Tigo respectively. For any value of q_2, MTN responds best with any value of q_1 that satisfies q_2. Similarly, for any value of q_1, Tigo responds best with any value of q_2 that satisfies q_1. Thus, the values of $q_1 and\ q_2$ which are the best response functions of MTN and Tigo respectively as shown above, are the profit maximizing values of MTN and Tigo respectively. In Nash equilibrium, both MTN and Tigo will be playing best responses so solving the above equations simultaneously. To obtain Nash Equilibrium, we substitute for Tigo's best responses [equation (10)] in MTN's best response functions [equation (11)] and we get the following:

$$q_1 = \frac{a - \frac{a - q_1 - \frac{\partial C_2(q_2)}{\partial q_2}}{2} - \frac{\partial C_1(q_1)}{\partial q_1}}{2} \quad (13)$$

Similarly, we substitute for MTN's best responses[equation (11)] in Tigo's best response functions [equation (10)] and we get the following:

$$q_2 = \frac{a - \frac{a - q_2 - \frac{\partial C_1(q_1)}{\partial q_1}}{2} - \frac{\partial C_2(q_2)}{\partial q_2}}{2} \quad (14)$$

Finally, the Nash Equilibrium is obtained at q_1^* and q_2^* as shown in equations (15) and (16) below:

$$q_1^* = \frac{a + \frac{\partial C_2(q_2)}{\partial q_2} - 2\frac{\partial C_1(q_1)}{\partial q_1}}{3} \quad (15)$$

$$q_2^* = \frac{a + \frac{\partial C_1(q_1)}{\partial q_1} - 2\frac{\partial C_2(q_2)}{\partial q_2}}{3} \quad (16)$$

CONCLUSION

In this paper, both the reaction function and the calculus equilibrium of the duopoly behavior of MTN and Tigo in the telecommunication market in Ghana have been studied. By analyzing the model, we have found that the best responses of both firms are the values that maximize the profits of each firm. The study predicts that both MTN and Tigo will eventually choose Nash Equilibrium output levels. There are potential theoretical implications in their choice of Nash Equilibrium, which is based on the recognition of both firms mutual interdependence. Thus, the two firms are likely to agree to act in unison in order to maximize total profit in the industry. Conclusively, MTN and Tigo will use self-imposing strategies to reduce output (ceteris paribus) in order to raise the price and increase their profit.

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