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Optimal Transportation and Spatial Integration of Regional Palm Oil Markets in Nigeria

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ABSTRACT

The poor quality of transportation infrastructure in Nigeria impacts negatively on the competitiveness of palm oil. This leads to increased inter-regional transportation cost, delayed time of arrival to the destination and lowered transaction efficiencies in the distribution chains. Primary and secondary data were used. Random sampling technique was used to collect data from 276 distributors in main palm oil markets. Data were analyzed using linear programming and Ravallion model at 0.05 α-level. Results of the data analyzes show that average cost of transporting palm oil from the production market to the consumption market was N5,831.9 per MT. Observed transportation cost was N60,724,830.5 while the optimal cost was N44,003,500.30 indicating a 38.0% reduction in total cost of transportation. Highest optimal allocations to the destination markets were Owerri-Jos (133,500 MT), Ondo-Lagos (107,200 MT) and Port Harcourt-Kano (82,000 MT) at minimum transportation cost of N5,750, N4000.7and N6500.0 per MT respectively. Two lag periods were identified signifying that it takes about 1-2 months for price information to spread across the markets by the model. Six of the 27 market pairs exhibited high short-run market integration for both lag periods with Port Harcourt-Abuja market pair indicating the highest (0.1 and 0.004). The lowest short-run market integration was recorded in Ondo-Minna market pair indicated by 1.4 and 17.4 respectively. Policies that will enhance redistribution of palm oil supply between producing and consuming regions should be pursued.

KEYWORDS

Market Integration, Optimal Allocation, Palm Oil, Nigeria, and Transportation Cost

INTRODUCTION

Stable food markets are of importance for economic development, political stability and the welfare of Nigerian farmers and middlemen. These markets are also important to consumers who spend a high proportion of their income on staples. The efficient transportation of these staples is important to all. The ways in which the transportation system is organized play a very important role in determining the livelihoods opportunities available to the economic agents both directly and indirectly.

Transportation adds value by making products available in the right place and at the right time. This can affect the production decision of farmers as they are likely to produce commodities which have high demand and consequently higher returns. The existence of poor quality or inadequate infrastructure may impact negatively on the competitiveness of agricultural producers through

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increasing internal transport costs, reducing levels of value-added at origin and lowering transaction efficiencies in the marketing chains. Physical transportation cost accounts for as much as 12% in the US, but in Nigeria, the percentage varies between 30 and 65% of delivery cost (MTC, 2013; Olayide in Adekanye, 1988). Walker (2000) has stated that the high cost of transportation in Nigeria is explained by an inefficient and uncoordinated transport system coupled with poor roads, reckless driving and absence of effective vehicle inspection and control.

Efficient transportation of goods and services is one of the stimulants of the national economy. In Nigeria, this is adjudged to be traumatic (Makhura, 2001). This has led to inefficient and poorly integrated agricultural markets in African countries. Agricultural marketing efficiency in these countries and indeed Nigeria is dismally low (Onyuma, Icart & Owuor, 2006; Phillip, Nkonya, Pender & Oni, 2008). This in turn, results from poor information transmission channels, inefficient communication systems and absence of official (government) price communication/media (Okoh, 1999).

The study seeks to find the optimal transportation schedule that will minimize the total cost of transporting palm oil from three production regions (Port Harcourt, Owerri and Ondo) to the various key destinations geographically scattered in Nigeria. The destinations are the markets where distributors/marketers carry the palm oil to (i.e. Lagos, Ibadan, Abuja, Sokoto, Kano, Kaduna, Maiduguri, Minna and Jos). Essentially, the problem becomes that of determining how much of a region's total palm oil output in a particular period, should go to a particular market. What is the "best" way to do this? That is, in an attempt to minimize total transportation cost of palm oil incurred by the distributors; what channels of physical distribution should each firm adopt, all acting within some binding constraints. These constraints are such that each firm cannot ship more than is available at the origin and the total shipment to the destination must at least be equal to the quantity required at the destination.

Another side of this problem is to maximize the nation's net revenue from palm oil industry. In other words, what is the price that must be paid either for a unit of the product at a particular production point and/or what price must be paid for the delivery of a unit of the product at a particular destination to achieve maximum revenue? When we try to discover the competitive prices charged both at the production and consuming points, we must be trying to achieve maximum net revenue at the same time that we are trying to minimize transportation cost.

A fundamental question that is relevant to this study is 'how effective is transportation in response to palm oil demand?' Transportation of palm oil from one location to the other constitutes a serious problem in Nigeria (Nwauwa, 2011). This is because the commodity is bulky and infrastructural facilities in the country have not been properly developed to handle evacuation of bulk materials at least cost. Rail system of transportation is most ideal for this situation but it is regrettably in lack with road system widely in use today (Otitolaiye, 2009).

Thus, this study therefore contends that imbalance in demand and supply of palm oil exists primarily due to inefficiency in the distribution of this commodity across the regional markets. This further leads to problem of price differential in different parts of the country. From past studies on transportation with the general consensus that the level and quality of infrastructure is low, a fundamental question that needs an urgent answer is "how does the Nigerian palm oil market perform under this situation?" In general, this study aims to evaluate optimal pattern of palm oil shipment that minimizes total cost of transportation and assess the level market integration of regional palm oil markets in Nigeria.

LITERATURE REVIEW

There has been quite lots of research over the years on the integration of various combinations of Nigerian foodstuffs markets. The principal studies in this area include those of Delgado (1986), Adekanye (1988a), Ejiga (1988), Dittoh (1994), Okoh (1999), Okoh & Akintola (1999), and Popoola & Rahji (2001), Nkang, Ndifon, & Odok (2007) and Nwauwa (2011). These studies covered market integration, price efficiency and pricing conduct of various foodstuffs and forest products (*gari*, rice, cowpeas, cassava roots, vegetables and sawn wood) in different regions of Nigeria. The price series used for the various studies were collected weekly or fortnightly by the researchers except for Okoh (1999) and Okoh & Akintola (1999), which used monthly series.

With the exception of Dittoh (1994), Okoh (1999), and Okoh & Akintola (1999), the studies used correlation coefficients and simple static regression equations of the form (Pi = a + bPj) to reach conclusions about the integration and efficiency of the markets for various foodstuffs. The general conclusion from these studies is that apart from *gari,* cowpeas and rice, the markets are poorly integrated. The findings of these studies are doubtful. This is because the bivariate correlation coefficient and static regression methods are beclouded with problems of overwhelming seasonal and secular trends, as well as the possibility of autocorrelation from a static model calibrated to non-stationary time series, leading to spurious correlations and inferential errors (Granger & Newbold, 1974; Harriss, 1979; Blyn, 1973; Delgado, 1986; Ravallion, 1986; Palaskas and Harriss-White, 1993). An important observation is that while markets have characteristics of perfect competition, the price correlation results show that they are not integrated. This conclusion could be as a result of faulty methodology.

Dittoh (1994; 2006)), Popoola & Rahji (2001), Uchezuba (2005), Heytens (1986), Tahir & Riaz (1997) have applied the Ravallion model to the study of market efficiency in agricultural markets in some parts of the world. The approach used an autoregressive distributed lag (ADL) model for testing "short–run" and "long–run" integration involving the correlation of price series of reference (urban) markets as well as non-price determinants of demand and supply. It is a one-way approach to market integration. Its basic flaws are the problems of simultaneity, failure to measure the level of integration where the flow between rural and urban areas reverses with the season, and inability to estimate the quantity of commodity traded at the spatial price, as well as the problems associated with non-stationary time series data.

The problem of non-stationarity in this study was overcome by subjecting the data set to stationarity or unit root test to ensure that the data operate at a constant mean and variance to avoid spurious result. The case of reverse causality is not feasible in Nigeria palm oil market since it is naturally impossible to grow oil palm in the consumption areas of this study. Also government policy could encourage importation of palm oil into the country thereby making consumption region (Northern Nigeria) source of supply. However, this can still not reverse the source of supply since there are no sea ports in Northern Nigeria, for now.

Finally, where there are many possible points of production and consumption, it is more difficult to determine the pattern of trade and the structure of prices using Ravallion model. This particular limitation of the Ravallion model necessitated the application of spatial equilibrium model (transportation model) in this study, useful in analyzing inter-regional price relationships and trading pattern where there are numerous consuming and producing regions. The latter optimizes allocations to the various demand market destinations at minimum transfer cost. In fact this, among other reasons, perfectly justifies the combination of Ravallion model with transportation linear programming model in this study. This is a major breakthrough. The Ravallion model analyzed the markets, pair-wise, isolating markets with spatial price relationships while the transportation model determined the inter-regional price relationships and trading pattern in all the markets simultaneously. The transportation model fills the gap in knowledge left by the Ravallion model by estimating both price relationship and the optimal quantity of commodity traded.

Research Hypothesis

The under- mentioned research hypotheses were formulated and tested for the study:

H01: Price variables are not stationary at their level
H02: Palm oil markets are spatially independent and inefficient

The second hypothesis is called market segmentation/price discriminatory hypothesis.

METHODOLOGY

Sources of Data

The study was in two stages. The first stage aimed at evaluating the inter-regional price relationships and trading pattern while the second stage involved determination of spatial price relations of the market pairs. Data for this study were obtained from both secondary and primary sources. Time series data of palm oil prices in Nigeria compiled by Nigeria Agricultural Extension Research and Liaison Services (NAERLS) augmented by Agricultural development Project (ADP) from 2008 – 2012 mostly on monthly retail prices were used. Monthly retail prices, instead of farm gate prices were used so as to incorporate those influences such as transportation, storage, processing and other activities that have bearing on the final consumer's purchase. Cross sectional primary data were sourced through survey instrument of well-structured questionnaire. 324 set of questionnaires were distributed, 38 were rejected for lack of adequate information, while 10 were not returned. Therefore, the analysis for this study was performed using data from only 276 marketers/distributors.

Data Analyses

Transportation Model

Transportation model was used to determine the routes that minimized total cost of transportation and optimal pattern of distribution of palm oil from the supply regions to the demand regions. The transportation problem (TP) is a spatial optimization procedure that minimizes interaction costs between origin and destination subject to capacity constraints, (Hitchcock, 1941; Taaffe *et al*, 1996). The aim of transportation model is to minimize total cost of transportation between origin(s) and destination(s). The objective of transportation model is to meet a set of restraints at minimum cost. It seeks to supply the product deficit locations from surplus quantities available in the locations at minimum cost (Beneke & Winterboer, 1973).Transportation problem involves the determination of optimal shipment patterns from supply region to demand region (Olayemi & Onyenweaku, 1999).

The linear programming method serves as basis to solve transportation problem. The value of the objective function which minimizes the cost for transportation and the number of unit that can be transported from source i to destination j are determined (Taghrid, Gaber, Mohamed, & Iman, 2009). If x_{ij} is number of units shipped from source i to destination j, the equivalent linear programming model will be the objective function (Prem & Hira, 1999):

$$\text{Minimize } z = \sum_{j=1}^{n}\sum_{i=1}^{m} C_{ij}X_{ij} \quad (1)$$

Subject to

$$\sum_{i=1}^{n} Xij = ai \tag{2}$$

for $i = 1, 2, \ldots m$

$$\sum_{j=1}^{n} Xij = bi \tag{3}$$

for $j = 1, 2, \ldots n$

$\neg X_{ij} \geq 0$ for all i to j

In solving this problem, there are "m" origins (called supply regions) that can supply "n" destinations (called demand regions) with palm oil. m is not necessarily equal to n. There is also the quantity of the commodity available at the i th supply origin, a_i and the quantity of the commodity required at the j th destination, b_j, and unit cost of transportation of moving the commodity from the i th origin to the j th destination, c_{ij}.

The problem is thus that of constrained cost minimization. The condition that $\Sigma ai = \Sigma bi$ means that total quantity available for distribution must be equal to the total quantity requirement at the destination. That is, total supply is equal to total demand. But in practice, the quantity of commodity available X_{ij} may not necessarily equal a_{ij} or b_{ij} because each a_{ij} may be distributed from i origin to more than one j-destination and each j-destination may receive consignment from more than one origin, provided of course, that the total quantity of the product distributed from all m origins is equal to the total assigned to n destinations. When total demand exceeds total supply, a dummy origin (supply region) is introduced to provide the excess demand (deficit) and when total supplies exceed total demand, a dummy destination (demand region) is created to receive the excess quantity.

Given the above, the cost minimizing pattern of palm oil shipment is given by the following linear primal programming model:

$$Min.Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij} \tag{4}$$

$$\sum_{j=1}^{n} X_{ij} = b_j, j = 1 \tag{5}$$

Equation 5 means that the quantity of palm oil shipped to a demand region is equal to the quantity required in that region.

$$\sum_{i=1}^{m} X_{ij} = a_i, i = 1, 2, \ldots m \tag{6}$$

Equation 6 shows that the quantity of palm oil shipped out of any supply region is equal to the quantity available in that region.

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j \tag{7}$$

Equation 7 implies that the quantity of palm oil available in the supply regions is equal to the total quantity required in the demand regions.

$X_{ij} \geq 0$, for all i and j is a restriction.

This simply requires that the quantities of palm oil shipped are non-negative.

Notations Used

$i = 1, 2, 3, \ldots, m$ denote the supply regions (origin)
$j = 1, 2, 3, \ldots, n$ denote the demand regions (destinations)

X_{ij} = the quantity of the palm oil moved from the i-th supply region to j-th demand region

C_{ij} = the unit cost of transportation from the i-th supply region to the j-th demand region.

a_i = the quantity of palm oil available at the i-th supply region

b_j = the quantity of palm oil required at the j-th demand region.

These variables are defined for a period of one year.

Nigeria neither imports nor exports palm oil for now[1]. Hence there is no need to incorporate import and export into the model.

The Dual Model

For the dual problem, a linear objective function and its constraints are maximized based on equations (4), (5) and (6) as follows;

$$\sum_{j=1}^{n} \sum_{i=1}^{m} Y_j - \sum_{j=1}^{n} \sum_{i=1}^{m} Y^i \tag{8}$$

Subject to:

$$P_j - P^i <= C_{ij} ni, j$$

Where,

Y_j = Demand requirements at destination j (i.e. demand constraints)
Y^i = Supply capacities at origin i (i.e. supply constraints)
P_j = market prices (N) of palm oil in the demand market
P^i = market prices (N) of palm oil in the supply market

P_j and P^i are unrestricted in sign when we consider strict equality.

C_{ij} = the unit cost of transportation from the i-th supply region to the j-th demand region.

Test for Stationarity

The first step in carrying out a time series analysis according to Masliah (2002), is to check for stationarity of the variables or price series. A price series is stationary if its mean and variance are constant over time. Non stationary stochastic series have varying mean or time varying variance. The price series in this study were first tested for stationarity. The purpose was to overcome the problems of spurious regression. The Augmented Dickey Fuller (ADF) was adopted to test for stationarity. This involves running a regression of the form:

$$\Delta P_{it} = \partial P_{t-1} + \sum_{i=1}^{P} \beta_1 \Delta P_{t-1} + \ell_{it} \ldots\ldots\ldots \quad (9)$$

Where = first difference operator, = 0, implies the existence of a unit root in Pi t or that the price series is non-stationary, i = commodity price series, i.e. palm oil, t = time indicator, e_{it} is the error term . The process is considered stationary if / / < 1, thus testing for stationarity is equivalent to testing for unit roots (<1). Therefore:

Ho: =0 the price series is non-stationary or existence of unit root
H1: < 0 the price series is stationary

The Ravallion Model

Ravallion model analysis was used to analyze the market integration of the palm oil market. Ravallion, (1986) proposed a methodology for testing market integration which incorporates both the law of one price and Granger-causality approaches. His model postulates a radial configuration of markets where local markets trade with a central market, in which the usual interaction of demand and supply determines a reference price upon which prices in all the local markets are based. The model assumes an autoregressive distributed lag relationship between prices of a commodity in the local market and those in the 'central' or 'reference' market.

According to Tahir & Riaz (1997), studying market integration using the Ravallion model could also be used to determine the leading market among the local markets. The basic Ravallion model seeks to determine whether a change in the price of the product in the local market is influenced by the change in the central market. The simplest form of the Ravallion model following Ravallion (1986) was given as:

$$PL = f\left(Pc, Xi\right) \quad (10)$$

Where:

PL = price in the local market
Pc = price in the central market
Xi = vector of non-price exogenous variables (e.g. intensity of residential construction, demand for cosmetics, confectioneries, bio-diesel, etc., and government policies) influencing demand for and supply of palm oil in the local market.

Index of Market Connection

The study considered whether there was market integration or not as well as whether the integration was low or high depending on the values of the indices obtained.

The regression coefficients, a1, a4 and a5 for Pl (t-1), Pc (t-1) and Pc (t-2) respectively, were used to calculate the indices as follows:

$$\text{IMC1} = \text{absolute } [\text{a1/a4}] = \left| a1/a4 \right| \tag{11}$$

$$\text{IMC2} = \text{absolute } [\text{a1/a5}] = \left| a1/a5 \right| \tag{12}$$

The IMC was developed by Timmer (1987) which is defined as the ratio of the local market coefficient to the central market coefficient. The Timmer index or index of market connection (IMC) lies between zero and infinity. The closer the IMC value to zero, the higher the degree of short-run market integration, hence:

$\text{IMC} \leq 1$ implies high short-run market integration

$\text{IMC} \geq 1$ implies low short-run market integration

$IMC = \infty$ implies no market integration

RESULTS

Optimal Pattern of Palm Oil Shipment

This study was to find a least cost shipping schedule that meets requirements at markets and supplies at origins where demand exceeds supply Dantzig, (1963), using Linear Program Solver (LiPS) version 1.11. This is an optimization package intended for solving linear, integer and goal programming problems. The explicit model was specified as follows:

The Model

$$Min\ Z = 5250 * X_{11} + 5150 * X_{12} + 5500 * X_{13} + 6500 * X_{14} + 6150 * X_{15} + 5350 * X_{16} + 6750 * X_{17} + 6500 * X_{18} + 5850 * X_{19} + 5000 * X_{21} + 5000 * X_{22} + 5250 * X_{23} + 6250 * X_{24} + 6500 * X_{25} + 5300 * X_{26} + 6750 * X_{27} + 6400 * X_{28} + 5750 * X_{29} + 4000 * X_{31} + 2500 * X_{32} + 5000 * X_{33} + 7500 * X_{34} + 7000 * X_{35} + 6500 * X_{36} + 7000 * X_{37} + 6000 * X_{38} + 6750 * X_{39};$$

Demand Constraints

$$X_{11} + X_{21} + X_{31} = 88000$$

$$X_{12} + X_{22} + X_{32} = 43000$$

$$X_{13} + X_{23} + X_{33} = 75000$$

$$X_{14} + X_{24} + X_{34} = 55000$$

$$X_{15} + X_{25} + X_{35} = 45000$$

$$X_{16} + X_{26} + X_{36} = 32000$$

$$X_{17} + X_{27} + X_{37} = 47000$$

$$X_{18} + X_{28} + X_{38} = 55000$$

$$X_{19} + X_{29} + X_{39} = 35000$$

Supply Constraints

$$X_{11} + X_{12} + X_{13} + X_{14} + X_{15} + X_{16} + X_{17} + X_{18} + X_{19} = 180000$$

$$X_{21} + X_{22} + X_{23} + X_{24} + X_{25} + X_{26} + X_{27} + X_{18} + X_{29} = 144000$$

$$X_{31} + X_{32} + X_{33} + X_{34} + X_{35} + X_{36} + X_{37} + X_{38} + X_{39} = 117000$$

Tables 1 & 2 represent the optimal transportation under the model. The model has 27 variables and 12 constraints with a minimized objective total transportation cost was N44,003,500.30. Under the model, average transportation cost of shipping one metric ton of palm oil from the producing regions to the destination markets was N5,831.

Accordingly, to minimize the transportation cost from the computer result of the analysis, the management should make the following shipment under the model:

Ship 82000 metric tons of palm oil from Port Harcourt to Kano at the cost of N6150 per ton;
Ship 46500 metric tons of palm oil from Port Harcourt to Maiduguri at the cost of N6750 per ton;
Ship 17800 metric tons of palm oil from Owerri to Lagos at the cost of N5000 per ton;
Ship 15500 metric tons of palm oil from Owerri to Ibadan at the cost of N5250 per ton;
Ship 71500 metric tons of palm oil from Owerri to Kano at the cost of N6250 per ton;
Ship 87700 metric tons of palm oil from Owerri to Kaduna at the cost of N5300 per ton;
Ship 15900 metric tons of palm oil from Owerri to Maiduguri at the cost of N6750 per ton;
Ship 94600 metric tons of palm oil from Owerri to Minna at the cost of N6400 per ton;
Ship 133500 metric tons of palm oil from Owerri to Jos at the cost of N5750 per ton;
Ship 107200 metric tons of palm oil from Ondo to Lagos at the cost of N4000 per ton;
Ship 91100 metric tons of palm oil from Ondo to Ibadan at the cost of N2500 per ton.

The main subject of interest in the model is that cost transportation per ton of palm oil determines how palm oil should be optimally allocated through the routes for efficient use of resources. This is due to the fact that optimal allocation follows cost minimization pattern. The shipment pattern produced by the program is optimal i.e. carried out at least cost. Any other allocation outside the optimal plan incurs extra cost or penalty and is **NOT** done at least cost. Optimal solution therefore, is obtained by making successive improvements to initial basic feasible solution until no further decrease in the transportation cost is possible. Consequently, an optimal solution is one where there is no other set of transportation routes that will further reduce the total transportation cost. The result agrees with the findings of Ogunfowora & Fetuga (1975) and Aneke (1977).

Penalty or Reduced Cost

The penalty or reduced cost indicates the amount by which profit will be reduced if any of the excluded routes is forced into the program. Table 1 presents the penalty figure for each route. There are two valid, equivalent interpretations of a reduced cost or penalty: First, a variable's reduced cost is the amount that the objective coefficient of the variable would have to improve before it would become profitable to give the variable in question a positive value in the optimal solution. For example, the variable Port Harcourt – Lagos (Table 1) has a reduced cost of -250, the objective coefficient of that variable would have to decrease by 250 units for the variable to become an attractive alternative to enter into the solution. A variable in the optimal solution, as in the case of Port Harcourt-Kano, automatically has a reduced cost of zero. This is because the variable is already recommended by the program. It is optimal, profitable, attracts least cost shipment and hence no penalty. Second, the reduced cost of a variable may be interpreted as the amount of penalty you would have to pay to introduce one unit of that variable into the solution. Again, if you have a variable with a reduced cost of -250, you would have to pay a penalty of 250 units to introduce the variable into the solution. In other words, the objective value would increase by -250 units in a minimization model. The higher the penalty or reduced cost of an excluded activity, the lower its chance of entering the optimal program. The logistic manager, under the model will give Ondo-Sokoto route the least consideration while Port Harcourt-Kaduna will be first considered for inclusion into the program. This is because Ondo-Sokoto route has the largest penalty of -2250 and Port Harcourt-Kaduna the least penalty of -50 per ton respectively.

Shadow Price

The optimal solution also gives a shadow price figure for each constraint (Table 2). The shadow price can be interpreted as the amount that the objective value would improve as the right-hand side, or constant term, of the constraint is increased by one unit. For example, in the model solution, the shadow price of -1000 on row12 means lifting one more metric ton of palm oil from Port Harcourt supply market would cause the objective function to improve by -1000, to a value of 44,004,500 (i.e. 44,003,500 - (-) 1000). Notice that "improve" is a relative term. However, in a minimization problem, the objective value would *decrease* if you were to *increase* the right-hand side of a constraint with a *positive* shadow price and vice versa. For example, Row1 has a positive shadow price of 5000 implying that to lift extra metric ton of palm oil from Port Harcourt to Lagos will cause the objective value to decrease by 5000 i.e. 44,003,500 - (+) 16250 = 43998500). Shadow prices are sometimes called dual prices, because they tell you how much you should be willing to pay for additional units of a resource. Based on our analysis, palm oil marketers should be willing to pay up to N5000 for each additional metric ton of palm oil shipped to Lagos.

Table 3 depicts the optimal plan for shipment of palm oil from the producing regions to the consuming regions. Palm oil marketers are therefore advised to distribute their commodity following the recommendations in the optimal plan. This will enable them maximize their resource use and make more profit. The result of the minimized objective value (N44,003,500) can be compared to the non-optimized total transportation cost or observed transportation cost of N60,724,830.5. This indicates a 38% reduction in the total transportation cost of shipping palm oil from the producing region to the consumption region in the study area. This suggests the advantage of the optimal plan over the original distribution schedule of the marketers. Hence the study directs the pattern of trade flow from "what is to what ought to be".

Dual Solution

Every linear programming model has a corresponding, mirror-image formulation called the dual. If the original model has *M* constraints and *N* variables, then its dual will have *N* constraints and *M* variables. Some interesting properties of the dual are that any feasible solution to the dual model provides a bound on the objective to the original, primal model, while the optimal solution to the dual has the same objective value as the optimal solution to the primal problem. It is also true that the dual of the dual model is, once again, the original primal model. However, in this specification, all the cost of marketing are equated to transaction or handling cost INSTEAD of transportation cost. In this study area, these transaction costs of marketing palm oil would include the following set of costs: 1) labor, 2) purchase price of palm oil, 3) containers, 4) produce levies, 5) transportation, 6) rent, 7) security and 8) interest on loans. Thus, the dual solution to the primal transportation model has 12 variables, 27 constraints and N44,003,500 objective value.

The dual solution determined the set of market prices for the product in the demand and supply regions which maximizes total excess value between the demand and supply regions. This is subject to the constraints that the price differentials between the market prices in the demand (P_j) and supply (P_{ij}) regions are equal to or less than the given transportation cost (Olayemi & Onyeweaku, 1999). But in real life situation, the difference between p_j and p_i may be greater than zero. From the result of this analysis, the optimum values of the market price at the supply region (P_i) and the optimum values of the market price at the demand region (P_j) indicate comparative location and price advantage of the regions. Hence the pairs of market that entered the optimal program are integrated while those not recommended by the program, there exists no market integration between them.

Inter-Regional Palm Oil Flow

Under the conditions of the models, palm oil is surplus in Port Harcourt, Owerri and Ondo and deficit in Lagos, Ibadan, Abuja, Sokoto, Kano, Kaduna, Maiduguri, Minna and Jos respectively (Figures 1-3). The general pattern of palm oil flow is Port Harcourt, Owerri and Ondo to the various demand markets of Lagos, Ibadan and the rest of the markets in Northern Nigeria (Figures 1, 2 & 3).

Port Harcourt, Owerri and Ondo export their surplus palm oil to the distant markets deficient of the commodity. Figure 4.1 displays optimal flow of palm oil in Port Harcourt distribution centre under the model. The same scenario is applicable to figures 2 and 3. The pattern of flow is from the production to the consumption markets but the reverse is not feasible.

Index of Market Concentration, IMC

Six of the market pairs (PHC-ABU, PHC-KAN, PHC-MIN, PHC-JOS, OND-LAG and OND-IBA) exhibited high short-run market integration for both lag periods. Also six market pairs (PHC-LAG, OWE-LAG, OND-ABU, OND-SOK, OND-KAN and OND-MAI) maintained high and low short-run market integration either at lag period 1 or 2. PHC-ABU market pair gave $IMC_1 = 0.12$ and $IMC_2 = 0.004$; and PHC-KAN market pairs also gave $IMC_1 = 0.11$ and $IMC_2 = 0.06$ etc (Table 4). These results confirmed the existence of short-run market integration which is either low or high in the market pairs. However, the degree of market integration is measured by how close the IMC values are close to zero. The closer the IMC to zero, the higher the degree of market integration, and thus, marketing efficiency. It can be concluded that these market pairs were not characterized by much market imperfections. Hence the hypotheses that palm oil markets are spatially independent and inefficient are therefore rejected. The roads linking the central markets to the local markets are good and motorable at all times. The traffic density along the routes is very high.

The remaining market pairs indicated low degree of market integration for both lag periods 1 and 2 respectively which signifies marketing inefficiency. The roads linking the markets here are circuitous and not easily motorable. The major problem is inadequate access road network. This results to high handling costs which are likely to introduce imperfections into the marketing system. Another important factor leading to the marketing inefficiency recorded for these market pairs can be explained in terms of speculation and/or shortage effect. Such abnormal situation like the fear of future price increases could cause this kind of an outcome in marketing (Popoola & Rahji, 2001).

The issue as to why two lag periods are used in the market integration study may arise. Firstly, palm oil is harvested seasonally that is during the dry season when oil palms bear plenty ripe Fresh

Fruits Bunch (FFB) from the months of February to May. This is due to low level of technology in the country in developing oil palm varieties capable of fruiting throughout the year.

Secondly, palm oil is storable. It is thus assumed that at least within one month and at most two months, the market information that is available would have been disseminated throughout the market by the price mechanism.

Thirdly, to use yearly data involves a lot of aggregation which may distort the data. This will also reduce the sample size to five observations instead of the sixty cases used which might lead to spurious regression results. The use of monthly retail price instead of wholesale price takes care of storage and other transaction costs incurred in the process of marketing palm oil. Distance to the market is always a major consideration in sourcing for palm oil (Table 4). Short distance to the market removes a lot of bottlenecks that lead to market inefficiencies.

CONCLUSION AND RECOMMENDATIONS

The results indicated interpretative differences in market integration and/or efficiency. The Ravalllion model showed that 27 market pairs are integrated and efficient. The transportation model showed that 17 market pairs are integrated. Under the Ravallion model, it takes about 1-2 months for market information to spread across the markets. The longer time it takes above this for market information to spread across the markets, the higher the level of inefficiency in the markets. Palm oil marketers should distribute palm oil following these routes: Port Harcourt to Kano at the cost of N6150 per ton; Port Harcourt to Maiduguri at the cost of N6750 per ton etc. These routes minimize total cost of transportation. This allows them to make a daily cost saving of N44,003,500. Palm oil arbitrage exists in 11 out of the 27 market pairs. These market pairs are integrated and therefore exhibits marketing efficiency. Zero allocation in the non-optimal routes implies that there is no trade between the market pairs, hence, no market integration.

The two models analyses show that marketing efficiency has not yet been reached in some of the markets. In other words, consumer markets have not yet become the price barometer for this commodity in those markets. This study can be extended by using economic and technical efficiency under stochastic cost functions. Also, additional data beyond the study period (2008 - 2012) can be used to evaluate changes that might have occurred since the market-level data used in this study was published.

The study therefore recommends policies that will enhance redistribution of palm oil supply between producing and consuming regions as well as reduce income inequalities between rural and urban inhabitants be pursued.

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ENDNOTES

[1] There is a ban on importation of palm oil in Nigeria since the year 2000 by the then Obasanjo administration. The reason is to encourage local production of the product and sustain growth of the industry. The current annual demand for palm oil alone is in excess of 1million tons. With domestic production at 785,000 MT there is thus a production deficit of over 215, 000 MT (RMRDC, 2008). This makes import necessary and export difficult.

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APPENDIX A

Table 1. Result of the linear programing analysis

VARIABLE	SHIPMENT QTY.	OBJ. COST	PENALTY
PHC- LAG	0	5250	-250
PHC- IBAD	0	5150	-1650
PHC- ABUJ	0	5500	-250
PHC- SOK	0	6500	-250
PHC- KAN	82000	6150	0
PHC- KAD	0	5350	-50
PHC- MAI	46500	6750	0
PHC- MIN	0	6500	-100
PHC- JOS	0	5850	-100
OWE- LAG	17800	5000	0
OWE- IBAD	0	5000	-1500
OWE- ABUJ	15500	5250	0
OWE- SOK	71500	6250	0
OWE- KAN	0	6500	-350
OWE- KAD	87700	5300	0
OWE- MAI	15900	6750	0
OWE- MIN	94600	6400	0
OWE- JOS	133500	5750	0
OND- LAG	107200	4000	0
OND- IBAD	91100	2500	0
OND- ABUJ	0	5000	-750
OND- SOK	0	7500	-2250
OND- KAN	0	7000	-1850
OND- KAD	0	6500	-2200
OND- MAI	0	7000	-1250
OND- MIN	0	6000	-600
OND- JOS	0	6750	-2000

Source: Data Analysis result

APPENDIX B

Table 2. Result of the linear programing analysis, RHS

Constraint	Value	RHS	Shadow Price
Row1	88000	88000	5000
Row2	43000	43000	3500
Row3	75000	75000	5250
Row4	55000	55000	6250
Row5	45000	45000	6150
Row6	32000	32000	5300
Row7	47000	47000	6750
Row8	55000	55000	6400
Row9	35000	35000	5750
Row10	180000	180000	0
Row11	144000	144000	0
Row12	117000	117000	-1000

Source: Data Analysis result

APPENDIX C

Table 3. Optimal plan for shipment of palm oil from the producing regions to the consuming regions. Source: Author's computation.

	LAG	IBA	ABU	SOK	KAN	KAD	MAI	MIN	JOS
PHC					82000 (6150)		46500 (6750)		
OWE	17800 (5000)*	15500 (5250)			71500 (6250)	87700 (5300)	15900 (6750)	94600 (6400)	133500 (5750
OND	107200 (4000)	91100 (2500)							

**Figure in parenthesis represents cost of transportation while the preceding figure is the optimal quantity of palm oil shipped from the producing region to the consuming region.*

APPENDIX D

Table 4. Regression result for the market pairs

Cent. mkt	Loc. mkt	Dist (km)	a_1	a_2	a_3	a_4	a_5	R^2	IMC_1	IMC_2	Classification
PHC	LAG	866	.741066 (1.0258)	1.4195 (.1456)	*.456298 (.7189)*	*.42552 (.1334)*	-2.9200 (9.219)	0.67	1.74	0.25	Low S/R MI in period 1 and High S/R MI 2
PHC	IBA	723	.26780 (.1245)	2.1572 (0.03690)	.017996 .5176722)	(.2015) (.1376)	0.149 (.07465)	0.46	1.35	1.79	Low S/R MI both periods
PHC	ABU	897	.015900 (1.9609)	0.1421 (0.888)	.208702 (.24056)	1.5008 (.442.)	3.4823 (0.2782)	0.76	0.12	0.004	High S/R MI both periods
PHC	SOK	1261	.945173 (1.3249)	.71300 (.67931)	1.211037 (.15939)	.13248 -(1.15)	-0.2562 (.41664)	0.68	7.1	3.68	Low S/R MI both periods
PHC	KAN	1362	-.13731 (1.0532)	-1.3023 (0.19823)	.34869 (.07406)	1.1631 (.2034)	2.0732 (0.044)	0.66	0.11	0.06	High S/R MI both periods
PHC	KAD	1235	.562540 (.11328)	.0696456 (.14048)	.0029555 (.15123)	.2275 (.1441)	.04509 (.1452)	0.35	2.47	12.4	Low S/R MI both periods
PHC	MAI	1518	.816136 (.07930)	.9451734 (.13249)	-.152693 (.13284)	.26394 (.1009)	.09784 (.1007)	0.71	3.09	8.34	Low S/R MI both periods
PHC	MIN	1025	.409851 (.13538)	-.288829 (.14129)	.0162148 (.12778)	.53571 (.1050)	.49428 (.1375)	0.81	0.76	0.82	High S/R MI both periods
PHC	JOS	878	.294307 (.12819)	.2806881 (.13968)	.0278013 (.18346)	.40348 (.1398)	.44105 (.1227)	0.48	0.72	0.66	High S/R MI both periods
OWE	LAG	746	.723563 (.07508)	.82356 (.97403)	.52364 (.50857)	.53556 (.3407)	.91634 (.974)	0.75	1.35	0.7	Low S/R MI in period 1and High S/R MI in 2
OWE	IBA	603	.08891 (.2113)	.213552 (.910008)	.31450 (.29100)	0.889 (2.132)	.29702 (.4141)	0.76	0.09	0.3	High S/R MI both periods
OWE	ABU	780	.823959 (.07829)	.940238 (.13195)	-.154664 (.106130)	.25702 (.1025)	.04823 (.1019)	0.71	3.2	17.0	Low S/R MI both periods
OWE	SOK	1141	.827606 (.07539)	-.162976 (.13733)	-.072507 (.106419)	.17794 (.1024)	.10348 (.1014)	0.70	4.65	7.99	Low S/R MI both periods
OWE	KAN	1142	.562540 (.11318)	.0696456 (.14047)	.0029555 (.151231)	.22716 (.1441)	.04509 (.1452)	0.35	2.47	12.4	Low S/R MI both periods
OWE	KAD	1115	.816136 (.07025)	.9451734 (.13249)	-.152693 (.132844)	.26394 (.1009)	.09784 (.1007)	0.71	3.09	8.34	Low S/R MI both periods
OWE	MAI	1300	.823563 (.07507)	-.161348 (.136804)	-.068352 (.104770)	.21359 (.1088)	.14790 (.0985)	0.71	3.85	5.56	Low S/R MI both periods
OWE	MIN	709	.571920 (.11103)	.028032 (.140395)	.0476865 (.150330)	.31315 (.1374)	.10161 (.1388)	0.38	1.82	5.61	Low S/R MI both periods
OWE	JOS	789	.568729 (.13831)	.7410665 (.14195)	-0.42552 (-0.1456)	.23694 (.1345)	.27772 (.1370)	0.73	2.4	2.04	Low S/R MI both periods
OND	LAG	320	.409851 (.13538)	-.288829 (.14129)	.0162148 (.127780)	.53578 (.1058)	.49428 (.1375)	0.81	0.76	0.82	High S/R MI both periods
OND	IBA	170	.294307 (.12819)	.2806881 (.13978)	.0278013 (.183468)	.40348 (.1398)	.44102 (.1287)	0.48	0.72	0.66	High S/R MI both periods
OND	ABU	600	.82760 (.0753)	0.2760 (.075369)	.60627 (.06975)	.07536 (.9801)	2.0753 (.6910)	0.82	1.0	0.4	Low S/R MI in 1 and High S/R MI period 2
OND	SOK	758	.177944 (.1032)	.27943 (.1329)	.79443 (.49916)	.44310 (.3249)	.10324 (.172)	0.84	0.4	1.7	High S/R MI in period 1 and Low S/R MI in 2
OND	KAN	1029	0.34868 (.10125)	.10348 (.10142)	.4868 (.4256)	.8681 (.0145)	.1014 (.0209)	0.82	0.4	3.4	High S/R MI in period 1 and Low S/ MI in 2
OND	KAD	794	.294307 (.12817)	.4375 (.96230)	.07128 (.5512)	.30751 (.2819)	.2819 (.2300)	0.63	1.0	1.0	Low S/R MI both periods
OND	MAI	1470	.40348 (.13946)	.0388 (.3876)	.4713 (.9842)	.81397 (.2880)	.13987 (.6838)	0.54	0.5	2.88	High S/R MI in period 1 and Low S/R MI in 2
OND	MIN	405	.44102 (.59001)	.10253 (.7763)	.1228 (.3501)	.02531 (.2287)	-0.3128 (.7761)	0.77	17.4	1.4	Low S/R MI both periods
OND	JOS	928	-.8922 (.8423)	.6517 (0.010)	.57892 (-.598)	.26576 (0.355)	.842 2 (0.984)	0.61	3.35	1.0	Low S/R MI both periods

Source: Result of data analysis, 2013

Note: Figures in parenthesis are standard errors

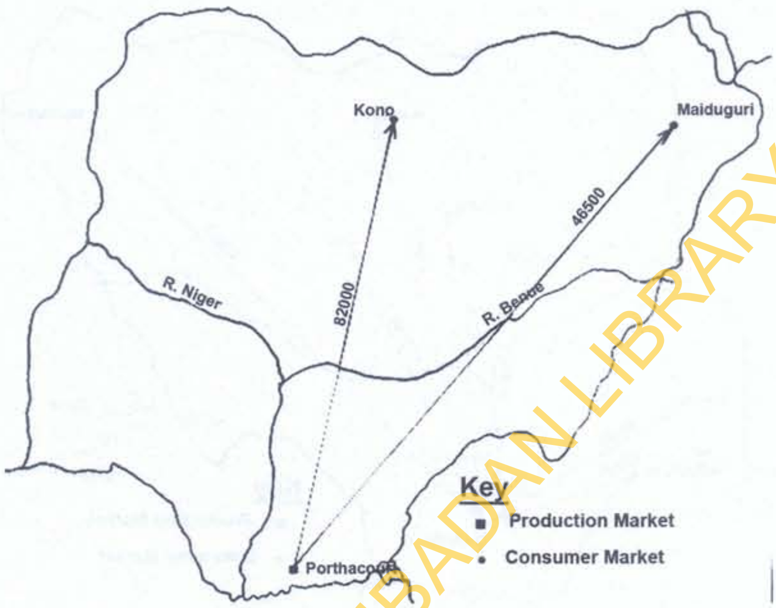
R^2 indicates the relevance in determining market integration by the method used

S/R = Short-rum

MI = Market Integration

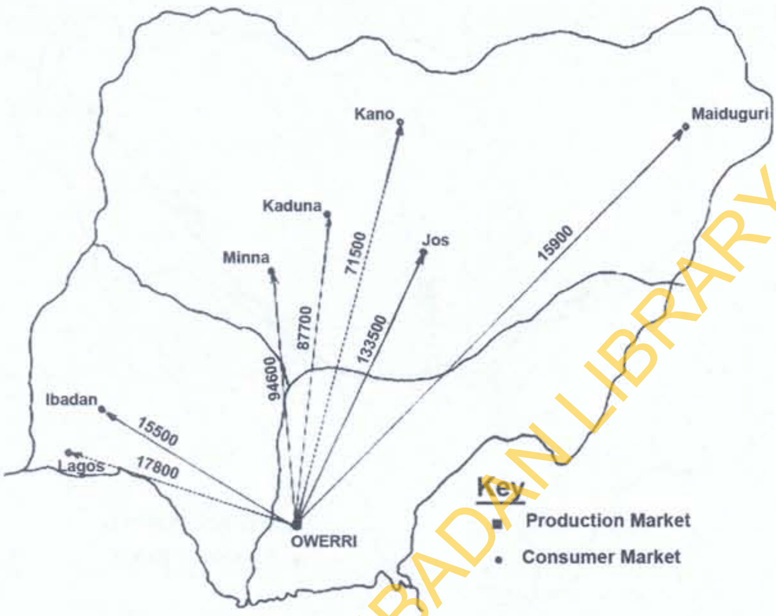
APPENDIX E

Figure 1. Map of Nigeria showing optimal shipment of palm oil in MT (Port Harcourt production market)



APPENDIX F

Figure 2. Map of Nigeria showing optimal shipment of palm oil in MT (Owerri production market)



APPENDIX G

Figure 3. Map of Nigeria showing optimal shipment of palm oil in MT (Ondo production market)