Vol. 7, No. 1
January-March, 2016
ISSN: 1947-9328

**An official publication of
the Information Resources
Management Association**

INTERNATIONAL JOURNAL OF

Operations Research and Information Systems

UNIVERSITY OF IBADAN LIBRARY

IGI PUBLISHING

Publisher of IT books, journals and cases since 1988
www.igi-global.com

Table of Contents

International Journal of Operations Research and Information Systems

Volume 7 • Issue 1 • January-March-2016 • ISSN: 1947-9328 • eISSN: 1947-9336

An official publication of the Information Resources Management Association

Research Articles

UNIVERSITY OF IBADAN LIBRARY

COPYRIGHT

The **International Journal of Operations Research and Information Systems (IJORIS)** (ISSN 1947-9328; eISSN 1947-9336), Copyright © 2016 IGI Global. All rights, including translation into other languages reserved by the publisher. No part of this journal may be reproduced or used in any form or by any means without written permission from the publisher, except for noncommercial, educational use including classroom teaching purposes. Product or company names used in this journal are for identification purposes only. Inclusion of the names of the products or companies does not indicate a claim of ownership by IGI Global of the trademark or registered trademark. The views expressed in this journal are those of the authors but not necessarily of IGI Global.

The *International Journal of Operations Research and Information Systems* is indexed or listed in the following: ACM Digital Library; Bacon's Media Directory; Cabell's Directories; DBLP; Google Scholar; IAOR Online; INSPEC; JournalTOCs; Library & Information Science Abstracts (LISA); MediaFinder; The Standard Periodical Directory; Ulrich's Periodicals Directory

International Journal of Operations Research and Information Systems
Volume 7 • Issue 1 • January-March 2016

Primal-Dual Links to Spatial Equilibrium Market Model for Palm Oil in Nigeria

L. O. E. Nwauwa, Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria

K. O. Adenegan, Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria

M. A. Y. Rahji, Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria

Oluwafemi Zaccheaus Olaniyi, Department of Agricultural Economics, Oyo State College of Agriculture and Technology Igboora, Oyo State, Nigeria

UNIVERSITY OF IBADAN LIBRARY

ABSTRACT

Distribution of agricultural produce is undertaken to bridge the gap between production and consumption arising due to spatial separation between areas of surplus and deficit. An investigation of primal-dual links to spatial equilibrium model and integration of palm oil markets in Nigeria was carried out using transportation model. Two-stage sampling technique was used to collect data from 3 markets and 276 distributors. Data were analyzed using linear programing model. Average cost of transportation per mode was bus (N17,173), truck (N10,357) and lorry (N5,831) respectively. Total transportation cost of N347,809,600.6k was observed compared to a minimized objective cost of N142,536,800.30k produced by the program. Highest optimal allocation to the destination markets using the different mode of transportation were Port Harcourt–Lagos by lorry (103,200 MT), Owerri–Maiduguri by truck (21,200 MT) and Ondo–Lagos by bus (19,800 MT) respectively. Subsidized cost of public transport facilities will reduce high cost of transportation.

KEYWORDS

Market Integration, Nigeria, Optimal Allocation, Palm Oil, Primal-Dual, Transportation Cost

INTRODUCTION

The distinguishing characteristics of spatial price equilibrium model lies in their recognition of the importance of space and transportation costs associated with shipping a commodity from a supply market to a demand market Nagurney (2002). This model is perfectly competitive partial equilibrium model, in that it assumes that there are many producers and consumers involved in the production and consumption of one or more commodities. The primary purpose for developing a spatial equilibrium model is to determine equilibrium values for prices, quantities and trade flows between spatially

DOI: 10.4018/IJORIS.2016010105

Copyright © 2016, IGI Global. Copying or distributing in print or electronic forms without written permission of IGI Global is prohibited.

(and/or temporally) separated regions or markets (Batterham & Macaulay, 1994). In the simplest form of the model the assumption of perfect competition between regions is adopted and supply, demand and transport costs between each of the regions are assumed to be known. A two-region, single-commodity model can be solved graphically (see Bressler & King 1970 or Tomek & Robinson 1981). Slightly more complex models can be solved algebraically using the concepts of consumer and producer surplus (Samuelson1952). As noted in Takayama & Judge (1971) and Takayama & MacAulay (1991), distinct model formulations are needed, in particular, both quantity and price formulations depending on the availability and format of the data.

In the spatial price equilibrium problem, one seeks to compute the quantity supply prices, demand prices, and trade flows satisfying the equilibrium condition that the demand price is equal to the supply price plus cost of transportation, if there is trade between the pair of supply and demand markets. If the demand price is less than the supply price plus the transportation cost, then there will be no trade. In other words, spatial price equilibrium is obtained if the supply price at a supply market plus the cost of transportation is equal to the demand price at the demand market. In the case of trade between the pair of markets; if the supply price plus the cost of transportation exceeds the demand price, then the commodity will not be shipped between the market pairs. In this model, a path represents a sequence of trade or transportation link; one may also append links to the network to reflect steps in the production process. It is the primal-dual character of the model that permits the connection of market models with the spatial model by linking the output of the commodity modelled at the market level to both price and quantity variables for the same commodity in the spatial equilibrium model.

Thus, there is a simultaneous determination of equilibrium prices and quantities in the market and spatial models. The result of this simultaneous solution is that if a higher price is generated for the commodity modelled in the spatial equilibrium model this price is transmitted to the market model. The market model solution will simultaneously generate a larger amount of the commodity since relative prices in the market component of the model will have changed in favour of the higher priced commodity. However, the market solution will be subject to the input-output coefficients and resource constraints so that with a price rise for the commodity, the imputed shadow values on the effective market resource constraints will also rise.

To incorporate the market models into a primal-dual spatial equilibrium model so as to replace the supply functions in the standard spatial equilibrium model, it is necessary that the market models be in a primal-dual form also. The market models can be transformed to dual models in the standard way using the method described in Baumol (1977). The rows become the columns and the right hand side the objective function, and the dual objective function is subtracted from the primal objective function. If the primal-dual form of the market models are solved as models in their own right then, as is the case with the spatial equilibrium model, the optimum value of the objective function is zero.

In spatial terms, the classical paradigm of the law of one price, as well as the predictions on market integration provided by the standard spatial price determination models (Enke, 1951; Samuelson, 1952; Takayama & Judge, 1972) postulate that price transmission is complete with equilibrium prices of a commodity sold on competitive foreign and domestic markets differing only by transfer costs. If we interpret primal linear program as classical "resource allocation problem, its dual can be interpreted as a resource valuation problem. These models predict that changes in supply and demand conditions in one market will affect trade and therefore prices in other markets as equilibrium is restored through spatial arbitrage. Thus this paper investigates the market model link to the spatial equilibrium model in two ways, by quantity through the primal part of the spatial equilibrium model, and by price through the dual part of the model.

UNIVERSITY OF IBADAN LIBRARY

LITERATURE REVIEW

Goodwin, Grennes & Wohlgenant (1990) opined that when investigating relationships between prices in market integration analysis, it is known that there is in general a simultaneity problem as economic theory does not always give final answers to which variable is exogenous. This same problem is, present in the analysis of supply chains. A multivariate system is used to forestall such problem. It is advantageous if one is interested in causal price changes as different hypotheses then are nested within a multivariate system (due to simultaneity, the results from such test are questionable if one uses only single equation approaches). When price series are non-stationary, the Johansen test is naturally recommended for such analysis.

Jyotish (2006) reviewed that in the sixties and the seventies, the methodological work on the measurement of pricing efficiency in agricultural commodity markets focused on pair-wise comparisons of price series data, i.e., the zero order correlation coefficient. Price series correlation is regarded as a convenient indicator of market integration [see Cummings (1967); Lele (1967; 1971), Jones (1972) and Thakur (1974)]. This approach has been strongly criticized despite its simplicity in the literature on market performance in rural areas (Blyn (1973); Harriss (1979); Ravallion, 1983; 1986). The studies based on bivariate correlation were found to have involved methodological flaws, the most serious one seems to have occurred due to their failure to recognize the possibility of spurious integration in the process of common exogenous trend (e.g., general inflation), common periodicity (e.g. agricultural seasonality) or auto-correlated and heteroscedastic residuals in the regression with non-stationarity price data (Barrett (1996) and Palaskas & Harriss-White (1993).

In the mid-1980s, several attempts were made to improve upon earlier methods. The most significant contribution to market integration method came from Ravallion (1986). In order to test alternative hypotheses of market integration, he proposed a dynamic model of spatial price differentials. Although this method mitigates the major methodological limitations of the bivariate correlation method, it still involves serious problems that result in inefficient estimators, which are used for testing alternative hypotheses of market integration and segmentation Palaskas and Harriss- White (1993).

Recent advances in time-series analysis especially those related to co-integration and error correction methods have led to an explosion in the literature on testing for food market integration in many countries including Nigeria [see for example, Asche, Bremnes, & Wessels, (1999); Goletti, Ahmed & Farid (1995); Adenegan & Adeoye (2011); Ohen, Abang & Idiong (2007); Moshood, Oladapo & Momoh (2011), Goodwin et al (1990), Okoh & Egbon (2005), Palaskas & Harriss-White (1993), Afolami (2001); Mafimisebi (2008) and Ghosh, (2000)].

Palaskas & Harriss-White's (1993) study, however, involves methodological defects inherent in the Engle & Granger (1987) method of co-integration. The most undesirable feature of the Engle & Granger (1987) procedure is that the test results may be very sensitive to the choice of the variable selected for normalization (i.e. the left- hand side in the regression). This problem is obviously compounded when there are more than two variables. Moreover, the method does not provide any procedure of testing multiple co-integrating vectors when there are three or more variables. Naturally, conducting the test of market integration properly by the Engle-Granger co-integration method, it is necessary to identify the central (exogenous) and peripheral (endogenous) markets. A much better way to resolve the problem is to use the multivariate co-integration method developed by Johansen (1988) and Johansen and Juselius (1990). This method treats all the variables as explicitly endogenous and takes care of the endogenity problem by providing an estimation procedure that does not require arbitrary choice of a variable for normalization. It also allows tests for multiple co-integrating vectors.

According to (Goletti *et al*, 1995), past research have identified various measures of market integration including correlation coefficients (Farruk, 1970; Lele, 1972; Jones, 1972; and Blyn, 1973), short and long-term tests of integration (Ravallion, 1986; Faminow and Benson, (1990), long-term multipliers and times to adjust (Boyd & Brorsen, 1986; Mendoza & Rosegrant, 1995), co-integration coefficients (Goodwin & Schroeder, 1991; Wyeth, 1992 and Palaskas & Harriss, 1991), causality and

UNIVERSITY OF IBADAN LIBRARY

centrality tests (Farris, 1979). However, a comparison of various measures as well as an analysis of the structural factors affecting these measures of market integration has been largely neglected, with the exception of the papers by Goodwin and Schroeder, (1991) and Faminow and Benson, (1990).

Delgado, (1986); Adekanye, (1988) and Ejiga, (1988) works on market integration studies have adopted the variance decomposition approach in their analysis which decomposed the variance of food-grain price into components. With Delgado's approach, market integration is defined as the existence of stable price spreads among markets in a given season, despite considerable variations in prices. The study concluded that the markets are not well integrated. The method is dependent on correlation of non-stationary time series with its flaw of possible spurious correlation and inferential errors.

Dittoh (1994) and Popoola & Rahji (2001) applied the Ravallion model to the study of market efficiency in Nigeria. The Ravallion 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 season, and colinearity among explanatory variables, as well as the problems associated with non-stationary time series data.

Okoh (1999) and Okoh & Akintola (1999) adopted the Mendoza and Rosegrant (1995) methodology, which applied a Bivariate Autoregressive Model (BAM) fashioned after the Ravallion approach but avoiding the problems associated with it by ascertaining the stationarity of data and differencing where necessary to obtain differenced stationary series. The studies showed that cassava root and gari markets in the study areas were weakly associated.

Nkang, Ndifon & Odok, (2007) study was concerned with testing for long-run market integration as well as determining the degree and the speed of price transmission in cocoa and palm oil markets using standard econometric techniques. Both cocoa and palm oil markets were found to be weakly integrated in the short-run and fully integrated in the long run with price transmission elasticities approximately 1.00, indicating that the Law of One Price (LOP) holds in the markets. The study concludes that producers of cocoa and palm oil in the study area benefit from spatial arbitrage as suggested by the perfect integration of the markets and the fulfillment of the law of one price.

The general conclusion from these studies shows that 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 auto-correlation from a static model calibrated to non-stationary time series, leading to spurious correlations and inferential errors (Granger and Newbold, 1974; Harriss, 1979; Blyn, 1973; Delgado, 1986; Ravallion, 1986; Palaskas and Harriss-White, 1993). The various studies on the integration of foodstuff markets suggest that major sources of poor integration and inefficiency include poor price information transmission channel, too many intermediaries and the high cost of transportation, as well as the sources and validity of price data. 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. As a result, various studies of Nigerian foodstuff markets have applied the Ravallion model or co-integration with little or major modifications such as Momoh and Agbonlahor (2007), Popoola and Rahji (2001) among others. But the Ravallion model and co-integration analysis are only good instruments for determining pair-wise spatial price equilibrium. They cannot determine the quantity traded at the spatial price in the markets.

This particular limitation of the models commonly used for estimating equilibrium market prices necessitated the application of spatial equilibrium model (transportation model) in this paper. This is useful in analyzing inter-regional price relationships and trading pattern where there are numerous producing and consuming regions. The latter optimizes allocations to the various demand market destinations at minimum cost of transportation. Ravallion model and co-integration analyses are used to analyze markets pair-wise while transportation model is used to determine the inter-regional price relationships and trading pattern in all the markets simultaneously. The transportation model is

UNIVERSITY OF IBADAN LIBRARY

also used to determine the optimal quantity of commodity traded at the spatial price which Ravallion or co-integration analysis cannot achieve. The identified weaknesses of the previous methods of analyzing market integration necessitated the application of spatial equilibrium model in solving optimal transportation and inter-regional integration of palm oil markets in Nigeria.

Spatial equilibrium model was applied by Enke (1951) to establish the connection between spatial price equilibrium problems and electronic circuit networks and Nagumey, (1992) applied variational inequality theory to the study of spatial equilibrium and disequilibrium. Also Samuelson (1952) and Takayama & Judge (1964; 1971) showed that the prices and commodity flows satisfying the spatial price equilibrium conditions could be determined by an external problem, in other words, a mathematical programming problem. However, these lack specific product and industry applications – hence the present study. These are therefore, wide gaps in research this study tries to fill.

METHODOLOGY

Sources of Data

Data for this study were obtained from primary and secondary sources. Cross sectional primary data were sourced through survey instrument of well-structured questionnaire. 324 set of questionnaires were distributed to palm oil distributors in 3 main palm oil supply marketers in Rivers, Imo and Ondo states representing highest producing areas in Nigeria. However, only 276 were valid for analysis. Data on palm oil production and consumption in Metric Tons (MT) were collected from Raw Material Research and Development Council (RMRDC) for 2012 while monthly retail price of palm oil from March 2008 to February 2012 were collected from Nigeria Agricultural Extension Research and Liaison Services (NAERLS).

Data Analyzes

Transportation Model

Transportation model was used to determine the routes that minimized total cost of transportation, optimal allocation and distribution pattern 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). 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; Ogunfowora & Fetuga, 1975 and Aneke, 1977).

The linear programming method serves as basis to solve transportation problem by transforming the later into the former. 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 is 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). A multi-mode transportation model involves the shipment of commodity using more than one mode of transportation. A generalized multi-mode transportation model is presented as follows:

$$Min.Z = \sum_{j=1}^{k} \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}^{k} X_{ij}^{k} \quad (1)$$

subject to:

UNIVERSITY OF IBADAN LIBRARY

$$\sum_{j=1}^{m} X^{k}ij = a^{k}i \quad for\ i = 1,2,...m \tag{2}$$

$$\sum_{j=1}^{m} X^{k}ij = b^{k}j \quad for\ j = 1,2,...n \tag{3}$$

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

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 $\sum ai = \sum bi$ 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. Also 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:

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

subject to:

$$\sum_{j=1}^{n} X_{ij}^{k} = b_{j}^{k}, j = 1,2,...n \tag{5}$$

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

$$\sum_{i=1}^{m} X_{ij}^{k} = a_{j}^{k}, j = 1,2,...m \tag{6}$$

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

$$\sum_{i=1}^{m} a_{i}^{k} = \sum_{j=1}^{n} b_{i}^{k} \tag{7}$$

UNIVERSITY OF IBADAN LIBRARY

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:

$X^k_{ij} \geq 0$

for all i and j is a restriction.

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

The Model

Generally, the full model (comprising all the 3 modes of transportation i.e. bus, truck and lorry) is presented as:

$$Minimize\ Z = \sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij}^{k} X_{ij}^{k} \quad (8)$$

subject to:

$$\sum_{j=1}^{n} X_{ij}^{k} \geq b_{j}^{k}, j = 1,2,\ldots n \quad (9)$$

$$\sum_{i=1}^{m} X_{ij}^{k} \geq a_{i}^{k}, i = 1,2,\ldots \mathrm{m}$$

$$X_{ij}^{k} \geq 0, for\ all\ i\ and\ j$$

The full model was applied in this study.

Notations Used

i = 1, 2, 3,…,m denote the supply regions (origin).
j = 1, 2, 3,…,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^k_{ij} = the unit cost of transportation (by mode) from the i-th supply region to the j-th demand region.
K = mode of transportation (i.e. bus, truck or lorry). Here, a mode is a means of transportation having its own characteristics, such as vehicle type and capacity, as well as specific cost measures.
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 (8), (9) and (10) as follows:

$$Maximize\ R = \sum_{j=1}^{n} \sum_{i=1}^{m} P_j Y_j - \sum_{j=1}^{n} \sum_{i=1}^{m} P_i Y^i \quad (11)$$

UNIVERSITY OF IBADAN LIBRARY

subject to:

$$P_j Y^i < C_{ij}^k \text{ n } i, j \quad (12)$$

where:

R = Total revenue from palm oil marketing.
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^k_{ij} = the unit cost of transportation (by mode) from the i-th supply region to the j-th demand region.
k = mode of transportation (i.e. bus, truck or lorry).

RESULTS

Optimal Allocations of Palm Oil from the Producing Regions to the Consuming Regions

The full model has 81 variables, 18 constraints and an objective value of N142, 536,800.The optimal pattern of palm oil shipment is illustrated in Tables 1 and 2. They indicate that under the model, palm oil marketers should distribute palm oil optimally as follows: 1000 metric tons of palm oil from Port Harcourt to Lagos by bus at the transportation cost of N17400; 70000 metric tons of palm oil from Port Harcourt to Kaduna by truck at the cost of N10000 etc.

The marketers should distribute the required quantities of palm oil to the various demand markets each for a daily cost saving of N142,536,800 against non-optimal plan of N347,809,600. The least total cost of transportation (N142, 536,800) obtained from the model indicates a 41.2% reduction in the existing total cost of transportation. Table 3 in shows the minimized cost of transportation and the optimal plan. Thus the result of the study suggests that palm marketers should transport their produce through these recommended routes for optimum profit. Under the model, the average transportation cost of shipping palm oil per metric ton from the producing regions to the destination markets is N11, 900.

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. Optimal solution is obtained by making successive improvements to initial basic feasible solution until no further decrease in the transportation cost was possible. Therefore, 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). Zero allocation to Minna by the transportation modes could be explained by terribly bad road network linking the route to the rest of the markets resulting to high cost of transportation thereby making shipment to those markets with high penalty. 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. Shadow prices are sometimes called dual prices, because they tell 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 N16250 for each additional unit of palm oil shipped to Lagos.

UNIVERSITY OF IBADAN LIBRARY

Table 1. Result of the linear programming analysis

Variable	Shipment Qty	Obj. Cost	Penalty
PHC-BUS-LAGOS	1000	17400	0
PHC-BUS-IBADAN	0	16250	-1500
PHC-BUS-ABUJA	0	17900	-1400
PHC-BUS-SOKOTO	0	19740	-2240
PHC-BUS-KANO	0	18150	-1000
PHC-BUS-KADUNA	0	17400	-1050
PHC-BUS-MAID	0	19950	-3950
PHC-BUS-MINA	0	17800	-300
PHC-BUS-JOS	35000	18750	0
PHC-TRUCK-LAGOS	0	9500	-750
PHC-TRUCK-IBADAN	0	8900	-1650
PHC-TRUCK-ABUJA	0	9750	-750
PHC-TRUCK-SOKOT	14000	10650	0
PHC-TRUCK-KANO	0	11250	-1600
PHC-TRUCK-KADU	70000	10000	0
PHC-TRUCK-MAID	0	8500	-1350
PHC-TRUCK-MINA	0	10000	1500
PHC-TRUCK-JOS	0	8900	-13650
PHC-LORRY-LAGOS	103200	5250	0
PHC-LORY-IBADAN	0	5150	-1400
PHC-LORRY-ABUJA	50000	5500	-1245
PHC-LORRY-SOKOTO	40800	6500	-689
PHC-LORRY-KANO	0	6150	-458
PHC-LORRY-KADU	70000	5350	0
PHC-LORRY-MAID	0	6750	-1750
PHC-LORRY-MINA	0	6500	-750
PHC-LORRY-JOS	0	5850	-14100
OWE-BUS-LAGOS	0	17000	-750
OWE-BUS-IBADAN	0	16750	-2000
OWE-BUS-ABUJA	28800	17250	0
OWE-BUS-SOKOTO	0	19300	-1800
OWE-BUS-KANO	0	17150	-7500
OWE-BUS-KADUNA	0	18250	-1900
OWE-BUS-MAID	0	19500	-3500
OWE-BUS-MINA	0	19250	-1750
OWE-BUS-JOS	0	18400	-15650
OWE-TRUCK-LAGOS	0	9000	-250
OWE-TRUCK-IBAD	0	8850	-1600
OWE-TRUCK-ABUJA	0	9000	-1100
OWE-TRUCK-SOKOT	0	11400	-1400

continued on following page

UNIVERSITY OF IBADAN LIBRARY

Table 1. Continued

Variable	Shipment Qty	Obj. Cost	Penalty
OWE-TRUCK-KANO	0	11400	-1750
OWE-TRUCK-KADUN	0	9750	-900
OWE-TRUCK-MAID	21200	14500	-6000
OWE-TRUCK-MINA	0	11500	-1500
OWE-TRUCK-JOS	0	11150	-15900
OWE-LORRY-LAGOS	43800	5000	0
OWE-LORRY-ABUJA	0	5000	-1500
OWE-LORY-IBADAN	0	5250	-6000
OWE-LORRY-SOKOT	20200	6250	0
OWE-LORRY-KANO	80000	6500	0
OWE-LORRY-KADUN	0	5300	-200
OWE-LORRY-MAID	0	6750	-2000
OWE-LORRY-MINA	0	6400	-150
OWE-LORRY-JOS	0	5750	-14250
OND-BUS-LAGOS	19800	10000	0
OND-BUS-IBADAN	0	7500	-1000
OND-BUS-ABUJA	0	15000	-5750
OND-BUS-SOKOTO	0	16750	-6500
OND-BUS-KANO	0	17000	-7100
OND-BUS-KADUNA	0	16500	-7400
OND-BUS-MAID	0	19250	-10500
OND-BUS-MINA	0	17500	-7250
OND-BUS-JOS	0	18000	-22500
OND-TRUCK-LAGOS	0	6050	-600
OND-TRUCK-IBADA	36200	4750	0
OND-TRUCK-ABUJA	0	7500	-1200
OND-TRUCK-SOKOT	0	12000	-4700
OND-TRUCK-KANO	0	14000	-7050
OND-TRUCK-KADUN	0	13500	-7350
OND-TRUCK-MAID	0	14750	-8950
OND-TRUCK-MINA	0	11350	-4050
OND-TRUCK-JOS	0	11750	-19200
OND-LORRY-LAGOS	1000	4000	0
OND-LORRY-IBADAN	98000	2500	0
OND-LORRY-ABUJA	0	5000	-750
OND-LORRY-SOKOT	0	7500	-2250
OND-LORRY-KANO	0	7000	-2100
OND-LORRY-KADUN	0	6500	-2400
OND-LORRY-MAID	0	7000	-3250
OND-LORRY-MINA	0	6000	-750
OND-LORRY-JOS	0	6750	-200

Source: Data Analysis result, 2013

UNIVERSITY OF IBADAN LIBRARY

Table 2. Result of the linear programming analysis, RHS or constraints

Constraint	Value	RHS	Dual Price
Row1	125000	125000	16250
Row2	98000	98000	14750
Row3	115000	115000	16500
Row4	75000	75000	17500
Row5	80000	80000	17150
Row6	70000	70000	16350
Row7	65000	65000	16000
Row8	46000	46000	17500
Row9	35000	35000	2750
Row10	0	36000	0
Row11	84000	84000	-7500
Row12	180000	180000	-11000
Row13	3800	28800	0
Row14	67200	67200	-7500
Row15	144000	144000	-11250
Row16	23400	23400	-7250
Row17	54600	54600	0
Row18	117000	117000	-12250

Source: Data Analysis result, 2013

Table 3. Optimal plan for shipment of palm oil from the producing regions to the consuming regions

	LAG	IBA	ABU	SOK	KAN	KAD	MAI	MIN	JOS
PHC-BUS	1000* (17400)**								35000 (18750)
PHC-TRU				14000 (10650)		70000 (10000)			
PHC-LOR	103200 (5250)		50000 (5500)	40800 (6500)		70000 (5350)			
OWE-BUS			28800 (17250)						
OWE-TRU							21200 (14500)		
OWE-LOR	43800 (5000)			20200 (6250)	80000 (6500)				
OND-BUS	19800 (10000)								
OND-TRU		36200 (4750)							
OND-LOR	1000 (4000)	98000 (2500)							

Source: Author's Computation, 2013
* Optimal quantity of palm oil shipped from the producing region to the consuming region
** Cost of transportation

UNIVERSITY OF IBADAN LIBRARY

Dual Solution and Spatial Price Equilibrium

The dual solution to the primal linear programming model also has 18 variables, 81 constraints and N142, 536, 800 objective value. Pairs of market that entered the optimal program implied trading pattern between the producing regions and the consuming regions hence, market integration. It can be inferred that no trade exists among those market pairs not recommended by the optimal program. Prices of palm oil at both the supply and demand regions of the markets pair corresponding to optimal palm oil allocation also exhibit optimality. Table 4 gives the pairs of markets that are integrated under the dual solution of the model. Out of the 81 market pairs, 17 (21%) are integrated while 64 (79%) are not. The reason for this is that palm oil arbitrage exists between the markets in the optimal solution. Zero allocation in the non-optimal routes implies that there is no trade between the markets pairs (no market integration). This result also indicates the level of efficiency of the market pairs. It suggests that the integrated markets exhibit marketing efficiency. This corroborates with the finding of Nkang *et al* (2007) that palm oil markets in Nigeria suggest spatial integration.

CONCLUSION AND RECOMMENDATIONS

The general pattern of palm oil shipment under the programming model was from the major producers of palm oil which also represent the surplus regions, to the marginal or deficit regions. The surplus regions also serve as export center while the deficit regions are major importers. Optimum allocation of palm oil from the producing regions to the distant markets was carried out at least cost under the market pairs recommended by the linear programming model. The model has 81 variables, 18 constraints and an objective value of N142, 536,800. This solution indicates that the distributors

Table 4. Spatial price equilibrium (primal-dual models)

Market Pair	Optimal Quantity (MT)	Optimal Price (N)	Transport Cost (N)
PHC-BUS-LAG	1000	78050	17400
PHC-BUS-JOS	35000	87428	18750
PHC-TRU-SOK	14000	79694	10650
PHC-TRU-KAD	70000	79481	10000
PHC-LOR-LAG	103200	78050	5250
PHC-LOR-ABU	50000	76688	5500
PHC-LOR-SOK	40800	79694	6500
PHC-LOR-KAD	70000	79481	5350
OWE-BUS-ABU	28800	76688	17250
OWE-TRU-MAI	21200	90027	14500
OWE-LOR-LAG	43800	78050	5000
OWE-LOR-SOK	20200	79694	6250
OWE-LOR-KAN	80000	86665	6500
OND-BUS-LAG	19800	78050	10000
OND-LOR-IBA	36200	78050	4750
OND-LOR-LAG	1000	78050	4000
OND-LOR-IBA	98000	72552	2500

Source: Data Analysis result, 2013

UNIVERSITY OF IBADAN LIBRARY

should transport the required quantities of palm oil to the various demand markets each for a daily cost saving of N142,536,800 against non-optimal plan of N347,809,600 to gain a 41% reduction in transportation cost. Lorry mode of transportation recorded the least cost of transportation. Average cost of transporting palm oil for bus was N17, 173, truck (N10, 357) and lorry (N5, 831).

The result of the primal-dual analysis indicated that the differences in the market prices between the 17 market pairs recommended by the program are equal to the unit cost of transporting palm oil between the cities. This confirms the existence of the 'law of one price' or geographical price advantage and commodity arbitrage among the regional markets. The optimum values of the price at the supply and demand markets also indicate the comparative advantages of the various regions – hence market integration. Market equilibrium was established by the determination of the optimal price and quantity of palm oil at the destination markets by the model.

About 79% of the markets analyzed did not trade among themselves suggesting marketing inefficiency. It can be inferred that market integration in Nigeria palm oil markets has not been fully obtained in all the markets. This may be caused by the palm oil marketers' lack of access to good quality marketing infrastructure and cost-effective marketing/distribution channels. The study concludes that palm oil marketers in Nigeria benefit from spatial arbitrage as suggested by integration of the markets and the fulfillment of the law of one price. Regional palm oil markets in Nigeria are poorly integrated but optimal allocation ensures supply to distant markets at reduced cost. Palm oil flows from surplus production regions to the various deficit consuming regions through cost – effective distribution channels. Improved road networks and subsidized cost of public transport facilities will reduce high cost of transportation.

UNIVERSITY OF IBADAN LIBRARY

REFERENCES

Adekanye, T. O. (1988). *Economics of inter-state marketing of farm products: a spatial analysis of transportation cost. Readings in agricultural marketing* (pp. 59–60). Longman Nigeria Limited.

Aneke, R. E. (1977). *Economics of least cost diet for pigs: A linear programming approach* Unpublished PhD Thesis, University of Ibadan, Ibadan, Nigeria

Asche, F., Bremnes, H., & Wessels, C. R. (1999). Product aggregation, market integration, and relationship between prices: An application to world salmon markets. *American Journal of Agricultural Economics*, *81*(3), 568–581. doi:10.2307/1244016

Batterham, R. L., & Macaulay, T. G. (1994). Price-linked farm and spatial equilibrium models. *Australian Journal of Agricultural Economics*, *38*(2), 143–170. doi:10.1111/j.1467-8489.1994.tb00537.x

Baumol, W. J. (1977). *Economic theory and operations analysis* (4th ed.). London: Prentice Hall.

Beneke, R.R. &Winterboer, R. (1973). *Linear Programming Applications to Agriculture*. Iowa state university press, AMES.

Blyn, G. (1973). Price series correlation as a measure of market integration. *Indian Journal of Agricultural Economics*, *28*, 56–59.

Bressler, R. G., & King, R. A. (I 970). Markets, prices, and interregional trade, Wiley, New York Delgado, C.L. (1986). A variance component approach to food grain market integration in Northern Nigeria. *American Journal of Agricultural Economics*, *68*, 70–79.

Dittoh, S. (1994). Market integration: The case of dry season vegetables in Nigeria. *Issues in African Rural Development*, *2*, 89–101.

Ejiga, N. O. O. (1988). Pricing efficiency for cowpeas in Northern Nigeria. In T.O. Adekanye, ed., Readings in Agricultural Marketing. Lagos: Longman Nigeria. Enke, S. 91951). Equilibrium among spatially separated markets: Solution by electronic analogue, Econometrica 10:40-47.

Faminow, M. D., & Benson, B. L. (1990). Integration of spatial markets. *American Journal of Agricultural Economics*, *72*(1), 49–62. doi:10.2307/1243144

Farris, B. (1979). There is method in my madness: Or is it vice versa? Measuring agricultural market performance. *Food Research Institute Studies*, *17*, 197–218.

Farruk, M. O. (1970). *The Structure and Performance of the Rice Marketing System in Eastern Pakistan*. Occasional Paper No. 31 (Ithaca, N.Y.) Cornell University

Goletti, F, Ahmed R & Farid N, (1995). Structural determinant of market integration. The case study of rice in Bangladesh. *The development economics Volume (XXXII-2)*

Goodwin, B. K., Grennes, T. J., & Wohlgenant, M. K. (1990). Testing the law of one price when trade takes time. *Journal of International Money and Finance*, *5*, 682–693.

Granger, C. W. J., & Newbold, P. (1974). Spurious regressions in econometrics. *Journal of Econometrics*, *2*(2), 111–120. doi:10.1016/0304-4076(74)90034-7

Harriss, B. (1979). There is method in my madness: Or is it vice versa? Measuring agricultural market performance. *Food Research Institute Studies*, *17*, 197–218.

Hitchcock, F. L. (1941). The Distribution of a Product from Several Sources to Numerous Loca lities. *Journal of Mathematical Physics*, *20*, 224–230.

Jones, W. O. (1972). *Marketing staple food crops in tropical Africa*. Ithaca, N.Y.: Cornell University Press.

UNIVERSITY OF IBADAN LIBRARY

Lele, U. (1972). Food marketing in India: private performance and public policy. Cornell University Press, Ithaca, N.Y. Mendoza, M.S. & Rosegrant, M.W. (1995). Pricing contact of spatially differentiated markets, Scott, G.J. (ed.) Price, Product and People: Analyzing Agricultural Markets in Developing Countries, Lynne Reinner Publishers, Inc. USA.

Momoh & Agbonlahor (2007). Food price differences and market integration in Oyo state *Asset Series* 2.1: 79-86

Moshood, O. (2007). *Oladapo & S.* Momoh.Food Price Difference and Market Integration in Oyo State, Nigeria. *International Journal of Agricultural Research 2 (1) ;* 69 – 74.

Nagumey, A. (1992). The application of variational inequality theory to the study of spatial equilibrium and disequilibrium. In W. E. Griffiths, H. Lutkepohl, & M. E. Bock (Eds.), *Readings in Econometric Theory and Practice* (pp. 327–355). Amsterdam: North-Holland.

Nagurney, A. (2002). *Spatial price equilibrium* (p. 01003). MA: Isenberg School of Management University of Massachusetts Amherst.

Nkang, M.N., Ndifon M.H. & Odok, G.N. (2007). Price transmission and integration of cocoa and palm oil markets in Cross River state, Nigeria: Implication for rural development *Agricultural Journal* 2 .4:457-463

Ogunfowora O. & Fetuga B. L. (1975). Least cost ration formulation for pig production. *Nig. J. Anim. Production.* 2 (2). December

Ohen S. B, Abang S.O. & Idiong I.C. (2007). Price Transmission and Market Integration: Vertical and Horizontal Price Linkages for Life Catfish in Nigeria.

Okoh, R. N. (1999). *An Analysis of oligopolistic pricing and market integration of cassava roots and products in Delta and Edo States, Nigeria.* Ph.D dissertation, University of Ibadan, Ibadan, Nigeria

Okoh, R. N., & Akintola, J. O. (1999). Pricing conduct of spatially differentiated markets. The case of cassava roots in Nigeria. *African Journal of Root and Tuber Crops*, *4*(2), 77–81.

Olayemi, J. K., & Onyeweaku, C. E. (1999). *Quantitative methods for business decisions*. Ibadan, Nigeria: Busode Printers.

Palaskas, T. B., & Harris, B. (1991). *Testing marketing integration: New approaches with case material from the West Bengal food economy.* Oxford Institute of Economic Analysis Palaskas, T.B. & B. Harriss-White (1993). Testing market integration: New approaches with case material from the West Bengal food economy. *The Journal of Development Studies*, *30*(1), 1–57. doi:10.1080/00220389308422304

Popoola, L., & Rahji, M. A. Y. (2001). Spatial market integration of *Terminalia ivorensis* sawn-wood markets in Nigeria. *Journal of Tropical Forest Products*, *7*(1), 1–9.

Prem, K. G., & Hira, D. S. (1999). "Operations research": An introduction, S. Chand and Co., Ltd. New Delhi, Ravallion, M. (1986). Testing market integration. *American Journal of Agricultural Economics*, *68*, 102–107.

RMRDC, Raw Material Research and Development Council. (2008). *The oil palm: report on survey of selected agricultural raw materials in Nigeria*. Abuja: RMRDC.

Samuelson, P. A. (1952). Spatial price equilibrium and linear programming. *The American Economic Review*, *42*(3), 283–303.

Taghrid, I., Gaber, E., Mohamed, G., & Iman, S. (2009). Solving transportation problem using object- oriented model. *International Journal of Computer Science and Network Security*, *9*(2), 76–85.

Takayama, T., & Judge, G. (1971). *Spatial and Temporal price and Allocation Model*. Amsterdam: North Holland Publishing Company.

Takayama, T., & Judge, G. G. (1964). Equilibrium among Spatially Separated Markets: A Reformulation. [October.]. *Econometrica*, *32*(4), 510–524. doi:10.2307/1910175

Takayama, T., & Judge, G. G. (1972). An interregional activity analysis model for the agricultural sector. *Journal of Farm Economics*, *46*(3), 349–365.

UNIVERSITY OF IBADAN LIBRARY

Takayama, T., & MacAulay, T. G. (1991). Recent developments in Spatial (Temporal) Equilibrium Models: Non-Linearity and Existence. In J.-B. Lesourd (Ed.), *International Commodity Market Modelling: Advances in Methodology and Applications* (pp. 71–89). London: Chapman and Hall. doi:10.1007/978-94-011-3084-4_3

Tomek, W. G., & Robinson, K. L. (1990). *Agricultural product prices* (3rd ed.). Ithaca, NY: Cornell University Press.

Wyeth, J. (1992). *The Measurement of Market Integration and Application to Food Security Policies.* Discussion Paper 314 (Brighton: Institute of Development Studies, University of Sussex).

ENDNOTES

1 There is a ban on importation of palm oil into 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 in Nigeria is in excess of 1million tons. With domestic production at 885,000 MT there is thus a production deficit of over 115, 000 MT (RMRDC, 2008). This makes import necessary and export difficult.

UNIVERSITY OF IBADAN LIBRARY