Determination Of Petroleum Product Network Flows To The Nigerian States By Software Gravity Model Techniques

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***Abstract*—Among oil producing and exporting countries (OPEC) Nigeria, a developing country, occupies an important place. Though most of the oil extracted is exported. Nigeria's own requirements are met by about 6% of its total oil production of Bonny light/medium varieties of crude oil supplemented by import of a heavy varity of crude oil from Venezuila, Kuwait and Saudi Arabia which are processed in three refineries owned by the Nigeria National Petroleum Cooperation (N.N.P.C) Nigeria also imports Petroleum Products from other countries to meet it domestic demand. This paper is concerned with a Gravity Model Technique of distribution of petroleum product flow in the states of the Federal Republic of Nigeria for meeting its domestic requirements.**

Keywords—Gravity model, Computer application Petroleum Product flow

1.0 INTRODUCTION

Among Oil producing and Exporting Countries (OPEC), Nigeria a developing country, occupies an important place. Though most of the oil extracted is exported, Nigeria's own requirements are met by about 6% of its total oil production of Bonny light/ medium variety of crude oil, supplemented by import of a heavy variety of crude oil from Venezuela, Kuwait and Saudi Arabia which are processed in three refineries owned by the Nigeria National Petroleum Corporation (N.N.P.C). Nigeria also imports petroleum products from other countries to meet its domestic demand. This paper is concerned with an analytical study of the flow of petroleum products on the transport network of Nigeria for meeting its domestic requirements. We consider five points of production (3 petroleum refineries and 2 ports of imports) and 19 points of consumption, which represent centroids of geographical areas of 19 states of the Nigerian Federal Republic. A suitable singly constrained gravity type interaction model is used to determine the flow of petroleum products form each origin point (production point) to each consumption point.

The gravity type model is calibrated to determine the value of deterrence parameter 'x' which gives the best "fit" in the sense that the available amount of petroleum product is distributed on the various origin-destination pairs/ links such that the consumption requirements are duly satisfied with the least discrepancy. The exercise of simulating volume of flows on origin-destination pairs/links is going to be useful in planning suitable transport network not only to serve the needs of the present but also to cater to the requirements for the future years. In this respect we need to know the demand for transport for future years. Being a member of O.P.E.C and operating in a fluctuating international market, Nigeria produces only that much of oil which it is able to feed into the market. However, despite wild fluctuations, it has been observed as per the least mean square error model that there is a steady growth of oil production in Nigeria. Once the future projections are made the exercise of determining flows on O-D pairs/links is carried out for 1990, 1995, 2000 and 2005.

We also consider an "export" model to determine the petroleum production available for domestic consumption not only for the present time but also for future years. The gravity type model when applied gives the flows on O-D pairs/links for future years. It is almost a truism that usefulness of a technique to yield sensible results is contingent upon various factors, the most important among these being the availability of requisite reliable database (Paul C Njoku 1990 andPaul C Njoku 1994)

2.0 DEVELOPMENT OF GRAVITY MODEL

Consider a set of regions labeled by i, j, k and the economic commodity petroleum products labeled by m. Assuming that there is only one mode of transport for the commodity, the mean cost of carrying a unit of m from origin i, or point of production, to destination j. or point of consumption, is $c^m ij$.

Let $t^m ij$ be the total flow of commodity m from region i to region j measured in million metric tonnes. For the purpose of convenience a subscript is replaced by an asterisk '*' to denote summation over that index. For example.

$$t^m i* = \Sigma j \ \ t^m ij \text{......................}(2.1)$$

is the total amount of commodity m produced in region i. Similarly, t^{m*} j is the total amount of commodity m used in the production of other commodities or consumed by a final demand sector in j. For convenience $T^m i$ and Wmj are defined to be total production and consumption in region i. Further, let T^m represent the total production in the whole system, so

$$T^m = \Sigma i\ T^m i = \Sigma j\ W^m j............... (2.2)$$

assuming the system to be "closed".

Further, to this consider $T^m i$ and $W^m j$ to be 'masses' of commodity m corresponding to the origin and destination of a spatial interaction between region i and j. Also consider the defined cost of transport $c^m ij$ to be a 'distance separating' origin and destination

Then a strictly Newtonian Interaction would be a $t^m ij$ defined by

$$t^m ij = k^m . \frac{T^m i W^m j}{(C^m ij)^2} . (2.3)$$

where k^m is a normalizing factor which ensures that

$$\Sigma i\ \Sigma j\ t^m ij = T^m \qquad (2.4)$$

That is

$$K^M = \frac{T^M}{\Sigma i\, \Sigma j\, T^m i W^m{}_m j/(C^m ij)^2} \qquad (2.5)$$

In order to accomdote the argument that spatial interaction for commodity flows may be governed by a distance function other than the Inverse Square Law, equation (2.3) could be written as

$$t^m ij = K^m\ T^m i\ W^m j\ f^m\ (C^m ij. .(2.6)$$

where f^m $(C^m ij)$ is some decreasing function of $C^m ij$ and K^m is now given by

$$K^m = \frac{T^m}{\Sigma i \Sigma j T^m i W^m j f^m (C^m ij)} \quad ....(2.7)$$

If it is assumed that independent estimates of T^m and that of $T^m i$ and $W^m j$ exist then an equation of the form (2.7) can always be used to estimate K^m. Thus equations (2.6) and (2.7), they stand, represent the Newtonian Gravity Model, and can easily be solved directly for tmij.

Strictly, a model of interregional commodity flows provides estimates of $t^m ij$, and hence of $t^m i*$, $t^m *j$, and $t^m **$. However$^m **= T^m$, and possibly $t^m i* = T^m i$, and $t^m *j = W^m j$, may be estimated directly from independent models. One sees that there are four possible cases:

(i)there is an independent estimate of T^m, but not of $T^m i$ or $W^m j$;

(ii)there is an independent estimate of T^m i, (which determines T^m), but not of $W^m j$;

(iii)there is an independent estimates of $W^m j$ (which determines T^m) but not of $T^m i$;

(iv)there are independent estimates of both $T^m i$ and $W^M j$ made in such a way that they determine T^m and that

$$\Sigma i\ T^m j = T^m \text{ and } \Sigma i\ W^m j = T^m$$

It is to be noted that in each of the cases (i) - (iv) two of the following equations should be satisfied.

$$\Sigma j\ t^m ij = t^m i* \qquad (2.8)$$

$$\Sigma i\ t^m ij = t^m *j \qquad (2.9)$$

$$\Sigma j\ t^m ij = T^m i \qquad (2.10)$$

$$\Sigma i\ t^m ij = W^m j \qquad (2.11)$$

Equations (2.8) and (2,9) should hold for case (i), equations (2.9) and (2.10) for case (ii) equation (2.8) and (2.11) for case (iii), and equations (2.10) and (2.11) for case (iv). However, it is observed that the model given by equations (2.6) and (2.7) does not satisfy these obvious consistency checks in any one case. Then one may view the situation in two ways firstly, the degree of fit between each side of appropriate eqs. in each case be used as one of the measures by the model is judged, and secondly, one can try to develop the model for further to incorporate the equations as constraints.

Case (i) **THE UNCONSTRAINED MODEL**

Based on this simplifying assumption in case (i) it is seen eqns. (2.6) and (2.7) continue to give the appropriate model for the case where one has an independent estimate of T^m but no fo $T^m i$ or $W^m j$.

Case (ii): **The Production Constrained model**

Here eqn. (2.10) acts as constraint on the total production in region i. One tries to find a set of normalizing factors to replace the factor k^m to ensure that eq. (2.10) is always satisfied. For this define $A^m i$ and modify (2.6) to read

$$t^m ij = A^m i\ T_m\ W^m j\ f^m\ (\ C^m ij).(2.12)$$

Substituting for tmij from (2.12) in (2.10) one gets

$$\Sigma j\ A^m i\ T^m i\ t^m *j\ f^m\ (C^m ij) = T^m i$$

or

$$A^m i\ T^m i\ \Sigma j\ t^m *j\ f^m\ (C^m\ ij) = T^m i$$

or

$$A^m i = 1/[\, \Sigma j\, t^{m*} f^m (C^m ij)] \quad (2.13)$$

So eqns(2.12) and (2.13) represent the case (ii) model incorporating eqn. (2.10) as a constraint.

Case (iii): **THE ATTRACTION CONSTRAINED MODEL**

Here eqn. (2.11) acts as a constraint on the total consumption. This is called the Attraction Constrained Model because the constraint operates on the total of the commodity attracted to a region. A set of normalizing factors $B^m j$ replaced K^m, and a similar calculation as in case (ii) gives

$$t^m ij = B^m j\, t^m i*\, W^m j\, f^m (C^m ij) \quad .(2.14)$$

$$B^m j = 1/[\, \Sigma i\, t^m i*\, f^m (C^m ij)] \quad (2.15)$$

Case (iv) **THE PRODUCTION ATTRACTION CONSTRAINED MODEL**

Both eqns (2.10) and (2.11) act as constraints and one needs to replace K^m by two sets of factors $A^m i$ $B^m j$ to enable one to modify the model appropriately. Equation 2.6 gets modified to as follows.

$$t^m ij = A^m i\, B^m j\, T^m i\, W^m j\, f^m (C^m ij) \quad .(2.16)$$

the factors are calculated by substituting tmij from eqn. (2.16) into eqns . (2.10) and (2.11), respectively, to give:

$$A^m i = \frac{1}{\Sigma j\, B^m j\, W^m j\, f^m (C^m ij)} \quad (2.17)$$

$$B^m j = \frac{1}{[\, \Sigma_i\, A^m j\, T^m{}_i\, f^m (C^m ij)]} \quad (2.18)$$

that eqns. (2.17) and (2.18) need to be solved iteratively.

FLOWS BASED ON GRAVITY MODEL

The models developed above need to be further specified before using them. Consider f^m $(c^m ij)$ to take the form d_{ij}. α) where d_{ij} is the distance in km between the centroid of geographical region i and the centroid of geographical region j , and α is the deterrence function parameter. Also the quantities $t^m i*$ and $t^m *j$ are replaced by and $W^m j$ respectively. So for case (ii), corresponding to production constrained situation, the model is written as follows

$$t^m{}_{ij} = A^m{}_i\, T^m{}_i\, W^m{}_j\, (d_{ij})^{-\alpha} \text{........} \quad (2.19) \text{ where}$$

$$A^m i = \frac{1}{\Sigma_j\, W^m{}_j\, (d_{ij})^{-\square}} \quad .(2.20)$$

3.0 This singly constrained model is preferred over the production consumption constrained model for the simple reason that the calibration procedure for the singly constrained model is relatively straight forward, in that a sequential search procedure may be used to arrive at the optimum value of the deterrence parameter α. On the other hand, the calibration procedure for the doubly constrained model is rather tedious and requires estimation of the deterrence parameter α along with the n- pairs of calibration constant Ai and B_j corresponding to iterations. Since the product A_i B_j is unique one may exploit this property t search for the convergence of A_i and B_j which are iterated separately. These unique balancing factor products. (A_iB_j)) are then used to calculate the flows for successive α values until the optimal value of the a parameter is identified. Apart from this computational complexity, it is also believed that the greater the number of constraints imposed the greater is the loss of information curtaining to natural interactions. One's endeavor might well. Therefore, be to achieve, as far as possible, the unconstrained version of the mode or use a singly constrained model, and only, if warranted by exigencies of the situation, then take recourse to a doubly constrained model. As mentioned earlier, Nigeria has 3 oil refineries located at Port Harcourt, Warri and Kaduna. Where as the first two are located at the port-towns in the Southern part, the third is located in the Northern part. The data pertaining to production and consumption of petroleum product for different years, in the Nigerian states, the relevant distances are compiled in Tables 4 and 5. Also one may consider Port Harcourt and Warri as ports of import from where the imported petroleum products are supplied to different states to meet their demand. The data for import are obtained based on the demand of each state for the petroleum production and the indigenous supply from the three refineries which are able only to partially meet the domestic demand). The production and quarter allocation of Oil to member state and total investment in exploration are shown in tables 2 and 3 and major processing units is shown in table 4. Petroleum consumption is shown in table 1 while Nigerian all imports is shown in table 7.(NNPC 2000, NNPC 2005, NNPC 2006 and NNPC 2007).

4.0 PROJECTED ESTIMATES OF FLOWS

From the point of view of estimating flows of petroleum product for domestic consumption using gravity model, there are 5 production points (3 refineries,2 ports of import) and 19 consumption points, corresponding to all the states of the Federal Republic of Nigeria. One may now apply the gravity model given by equations (2.19) and (2.20) and estimate sequentially the flow on origin-destination pairs, for different values of & starting from & =0.001 and =0.01 in steps of 0.001. Data used for these estimates are taken from table 5. It is observed that the best "phase fit" is obtained for & =0.002 in the sense that the petroleum product distribution in the various origin-destination pair/links is such that

GRAVITY MODEL (BASED ON REGRESSION MODE OF PRODUCTION CONSUMPTION)

For 1990

	0.21	0.20	0.33	0.07	0.06	0.10	0.29	0.16	1.00	0.17	0.09
	0.21	0.21	0.33	0.07	0.06	0.10	0.29	0.16	1.00	0.17	0.09
Tij =	0.05	0.07	0.01	0.01	0.02	0.14	0.03	0.22	0.04	0.02	0.02
	0.068	0.67	1.07	0.22	0.18	0.33	0.21	0.51	3.26	0.55	0.30
	0.23	0.22	0.36	0.07	0.06	0.11	0.31	0.17	1.08	0.18	0.10
Colum, Sum	1.37	1.37	2.15	0.44	0.36	0.66	1.25	1.02	6.56	1.12.	0.61
Specified - Consumption	1.37	1,34	2.15	0.44	0.36	0.65	1.25	1.03	6.56	1.12	0.61

								Row Sum	Specf Production
0.16	0.19	0.08	0.15	0.05	0.11	0.04	0.22	3.58	3.58
0.16	0.20	0.08	0.15	0.05	0.11	0.04	0.22	3.58	3.58
0.04	0.04	0.02	0.03	0.01	0.02	0.01	0.05	0.80	0.80
0.53	0.64	0.25	0.50	0.16	0.36	0.15	0.72	11.69	11.69
0.17	0.21	0.08	0.17	0.05	0.12	0.05	0.24	3.89	3.89
Colum Sum	1.06	1.28	0.50	1.01	0.32	0.73	0.29	1.46	
Specf Consumpt	1.06	1.28	0.50	1.01	0.33	0.73	0.29	1.46	.................(2.2 1a)

For 1995

	0.24	0.24	0.38	0.08	0.0	0.12	0.12	0.18	1.16	0.20	0.11
	0.24	0.24	0.38	0.08	0.06	0.12	0.12	0.18	1.16	0.20	0.11
	0.05	0.05	0.09	0.02	0.01	0.03	0.05	0.04	0.26	0.04	0.02
Tij =	0.88	0.88	1.38	0.28	0.23	0.43	0.80	0.66	4.21	0.71	0.40
	0.29	0.29	0.47	0.09	0.08	0.14	0.27	0.22	1.41	0.24	0.13
Colum Sum	1.71	1.70	2.69	0.54	0.46	0.83	1.56	1.28	8.19	1.39	0.77
Specf Con.	1.71	1.68	2.69	0.55	0.46	0.82	1.56	1.28	8.21	1.40	0.76

								Row Sum	Specf. Production
0.19	0.23	0.09	1.18	0.06	0.13	0.05	0.26	4.16	4.16
0.19	0.23	0.09	0.18	0.06	0.13	0.05	0.26	4.16	4.16
0.04	0.05	0.02	0.04	0.01	0.03	0.01	0.06	0.93	0.93
0.69	0.83	0.32	0.65	0.21	0.47	0.19	0.94	15.15	15.15
0.23	0.27	0.11	0.22	0.07	0.15	0.06	0.31	5.05	5.05
Colum Sum	1.34	1.51	9.63	1.26	0.40	0.91	0.36	1.82	
Specf Con.	1.32	1.60	0.62	1.27	0.41	0.91	0.37	1.83	...................(2.21b)

For 2000

	0.28	0.27	0.43	0.09	0.07	0.13	0.25	0.21	1.32	0.21	0.12
	0.28	0.28	0.43	0.09	0.07	0.13	0.25	0.21	1.32	0.21	0.13
Tij =	0.06	0.06	0.10	0.02	0.02	0.03	0.06	0.05	0.29	0.05	0.03
	1.08	0.08	1.69	0.34	0.29	0.53	0.96	0.81	5.17	0.88	0.49
	0.36	0.36	0.68	0.11	0.10	0.17	0.33	0.27	1.73.	0.30	0.16
Colum, Sum	2.05	2.04	3.23	0.65	0.55	0.99	1.87	1.53	9.82	1.67.	0.92
Specified - Consumption	2.05	2.02	3.23	0.66	0.55	0.98	1.88	1.54	9.88	1.68	0.91

							Row Sum	Specf Production
0.21	0.26	0.10	0.07	0.15	0.06	0.30	4.74	4.74
0.22	0.26	0.10	0.07	0.15	0.06	0.29	4.74	4.74
0.05	0.06	0.02	0.01	0.03	0.01	0.06	1.05	1.05
0.85	0.02	0.40	0.26	0.57	0.23	0.15	18.60	18.60
0.28	0.34	0.13	0.08	0.19	0.08	0.38	6.20	6.20

Colum Sum	1.60	1.94	0.75	1.52	0.49	0.44	2.18	
Specf Consumpt	159	1.92	0.75	1.52	0.49	0.44	2.19	. (2.2 1c)

For 2005

	0.31	0.30	0.49	0.10	0.08	0.15	0.28	0.23	1.48	0.25	0.14
	0.31	0.31	0.48	0.10	0.08	0.15	0.28	0.23	1.48	0.25	0.14
	0.07	0.07	0.11	0.02	0.02	0.03	0.06	0.05	0.33	0.06	0.03
Tij =	0.28	0.28	1.01	0.41	0.34	0.62	0.17	0.95	6.13	1.04	0.58
	0.42	0.42	0.68	0.14	0.11	0.20	0.39	0.32	2.05	0.35	0.19
Colum Sum	2.39	2.38	3.77	0.76	0.64	1.16	2.18	1.79	11.5	1.95	1.08
Specf Con.	2.39	2.35	3.77	0.77	0.64	1.15	2.19	1.79	11.5	1.96	1.07

								Row Sum	Specf. Production
0.24	0.29	0.11	0.23	0.07	0.16	0.01	0.33	5.32	5.32
0.24	0.29	0.11	0.23	0.07	0.16	0.07	0.33	5.32	5.32
0.05	0.06	0.03	0.05	0.02	0.04	0.01	0.07	1.18	1.18
1.00	1.21	0.47	0.95	0.30	0.68	0.27	0.36	22.06	22.06
0.33	0.40	0.16	0.31	0.10	0.23	0.09	0.05	7.35	7.35

Colum Sum	1.87	2.26	0.88	1.77	0.57	1.27	0.51	2.55	
Specf Con.	1.85	2.24	0.88	177	0.57	1.28	0.51	2.36	..................(2.21d)

The, consumption requirements are satisfied. The relevant simulated matrices for T^m_{ji} are given by equations (2.21a, b, c, d) as the “least” discrepancy property) for target years 1990,1995,2000,2005 respectively. Each flow matrix shows not only the 95 (5*19) values for t^m ij are given (I=1,2.,5 j =1,2.19) but also the row sums and column sums and the specified production and consumption data for comparison between specified and estimated flows. It is seen that while the row sums exactly match with the corresponding production data, the column sums do match with consumption data, corroborating the fact that the gravity model used is production constrained (singly constrained). It has been observed that getting values of proper data for use in an application of a model is a difficult task. Generally speaking; the relevant data required for use in any analysis is extrapolated’ or ‘derived’ from a form not directly usable rather than acquiring it in the desired form to start with. The present exercise is no exception. Considering that one wants to apply the gravity model to obtain flows of petroleum products on Nigeria’s transport network for planning purposes the data in requirements pertain basically to production at refineries and import of petroleum products at ports of import (origin), as well as the product consumption in 19 stations (destinations) and distances represented by origin destination node pairs/links. While the data pertaining to distances are readily available, one needs to extract or derive data pertaining to production and import and consumption of petroleum products for future years. This has been done by estimating petroleum production and import and consumption of petroleum products for future years. This has been done by estimating petroleum production and consumption on the basis of regression equation given respectively by equations (2.22) and (2.23) as identified from the available cross-sectional and time-series. It is known that most of the crude oil produced by Nigeria is exported barring a meager 6% of total production .Small quantity of crude plus some special quality imported from Venezuela/Saudi Arabia and Kuwait, are sent to three refineries to produce petroleum products for domestic use. Assuming that this practice continues, production consumption data for future years have been estimated as in Table 1 Petroleum product consumption is celebrated as thus

$Y1=0.114*10^7 + 0.118*10^7x$; $R^2=0.987$

$(0.404*10^6)$ $(0.719*10^5)$

{98.7%} {99.9%} [99.9%] . (2.22)

Y1 is the total petroleum product consumption in tones and X is time in years (1973=0).

$Y2 = -0.718*10^5+0.327*10^5x$; $R^2=0.823$

$(0.721*10^5)$ $(0.45*10^4)$

{16.4%} {99.9%} [99.9%].(2.23)

where Y2 is the crude oil production in million barrels and x is time in years (1973=0).

Equation (2.23) indicates that despite wild fluctuations in production of crude oil; there is a steady growth oil production in evidence over the relatively long time-span for consideration. In order to remain in tune with the fluctuating crude oil price in the international market and the responding quota fixed for oil production by OPEC for Nigeria (Paul C Njoku 2003)

5.0 EXPORT MODEL.

Since Nigeria is an oil producing and exporting country, one may choose to analyze production-consumption problems related to petroleum products using a suitable export model. A simple export model may be considered to be the form:

$$E_t^m=E_o^m (1+r1)^t \qquad \text{.........(2.24)}$$

Where E_t^m = quantity of crude oil exported in t^{th} year

E^m_0 = quantity of crude oil exported in the base year

r1= export growth rate

t = time in year (1973=0).

This model characterizes the compound growth of crude oil export over the time period of observation. It is well known that the compound growth rate is smaller than the simple growth rate. This model, in fact, can be applied to export figures related to the commodity. Here, the concern is with the export of crude oil. Taking logarithm on both sides of equation (2.24), one gets log E_t^m =Log E^m_o = Log (1+ r1) t…..(2.25)

The parameters of this straight line equation can be determined by obtaining a linear regression plot of E_t^m versus t. For Nigerian situation the form of relationship among Log E_t^m it is as follows:

$$\text{Log } E_t^m = 9.4 + 0.1938\, t,\ R^2 = 0.852$$

(0.36) (0.0237)

(99.9%) {95.9%} [16.4%] …..(2.26)

Comparing equation 2.26 with eqn. 2.25 one gets Log(1+r1) = 0.1938 Log E^m_o = 9.4 suggesting a steady export growth rate approximately 5%. On the basis of equation (2.26) one may generate estimates of export for future years. From the data so generated, one may derive the data corresponding to production as given in Table 6a, 6b.

For 1990

	0.15	0.14	0.23	0.05	0.04	0.07	0.23	0.11	0.70	0.12	0.07	0.11
	0.15	0.14	0.23	0.05	0.04	0.07	0.23	0.11	0.70	0.12	0.07	0.11
Tij =	0.03	0.03	0.05	0.01	0.01	0.02	0.13	0.02	0.16	0.03	0.01	0.03
	1.78	0.77	1.23	0.25	0.21	038	0.31	0.59	0.75	0.64	0.35	0.61
	0.26	0.26	0.41	0.08	0.07	0.12	0.34	0.20	1.25	0.21	0.12	0.20
Colum,	1.37	1.35	2.15	0.44	0.36	0.66	1.25	1.03	6.56	1.12.	0.61	1.06

Sum - 1.37 1.34 2.15 0.44 0.36 0.65 1.25 1.03 6.56 1.12 0.61 1.06
Specf.

							Row Sum	Specf Production
0.14	0.05	0.11	0.03	0.08	0.03	0.16	2.52	2.52
014	0.05	0.11	0.03	0.08	0.03	0.16	2.52	2.52
0.03	0.01	0.02	0.01	0.02	0.01	0.03	0.56	0.56
0.73	0.29	0.58	0.19	0.42	0.17	0.83	13.46	13.46
0.24	0.10	0.19	0.06	0.14	0.06	0.28	4.49	4.49

Colum Sum 1.28 1.50 1.01 0.32 0.73 0.29 1.46
Specf
Consumpt 1.28 1.50 1.01 0.32 0.73 0.29 1.46 (2.27 a)

For 1995

0.19	0.18	0.30	0.06	0.05	0.09	0.27	0.14	1.90	0.15	0.08	0.14	
0.19	0.18	0.29	0.06	0.05	0.09	0.27	0.14	1.90	0.15	0.08	0.15	
0.04	0.04	0.07	0.01	0.01	0.02	0.14	0.03	0.20	0.03	0.02	0.03	
Tij =	0.97	0.96	1.53	0.31	0.26	0.47	0.99	0.73	4.66	1.79	0.43	0.75
0.32	0.32	0.51	0.10	0.09	0.15	0.40	0.24	1.55	0.26	0.14	0.25	

Colum 1.71 1.68 2.69 0.55 0.46 0.82 1.66 1.28 8.21 1.40 0.76 1.33
Sum 1.71 1.68 269 0.55 0.46 0.82 1.66 1.28 8.21 1.40 0.76 1.32
Specf
Conspt.

							Row Sum	Specf. Production
0.10	0.07	0.14	0.04	0.10	0.04	0.20	3.23	3.23
0.18	0.07	0.14	0.04	0.10	0.04	0.20	3.23	3.23
0.04	0.02	0.03	0.01	0.02	0.01	0.04	0.72	0.72
1.91	0.35	0.72	0.23	0.52	0.21	1.04	16.17	16.17
0.30	0.12	0.24	0.06	0.17	0.07	0.35	5.57	5.57

Colum Sum 1.60 0.62 1.27 0.41 0.91 0.37 1.82
Specf Con. 1.60 0.62 1.27 0.41 0.91 0.37 1.83 ....(2.27 b)

For 2000,

0.24	0.23	0.38	0.08	0.06	0.011	0.32	0.18	1.15	0.20	0.11	0.11	
0.24	0.24	0.38	0.08	0.06	0.11	0.32	0.18	1.15	0.20	0.11	0.11	
Tij =	0.05	0.05	0.08	0.02	0.01	0.03	0.15	0.04	0.26	0.04	0.02	0.03
0.14	1.12	1.79	0.36	0.30	0.55	0.14	0.85	5.47	0.93	0.51	0.61	
0.38	0.37	0.60	0.12	0.10	0.18	0.45	0.28	1.83	0.31	0.17	0.20	

Colum, 2.05 2.02 3.23 0.66 0.55 0.98 1.97 1.54 9.85 1.68. 0.92 1.5
Sum - 2.05 2.02 3.23 0.66 0.55 0.98 1.98 1.54 9.85 1.68 0.91 1.5
Specf.

							Row Sum	Specf Production
0.22	0.09	0.18	0.06	0.13	0.05	0.26	4.12	4.12
022	0.09	0.18	0.06	0.13	0.05	0.26	4.12	4.12
0.05	0.02	0.04	0.01	0.03	0.01	0.06	0.92	0.92
0.07	0.42	0.84	0.27	0.61	0.24	1.22	19.64	19.64

0.36	0.14	0.28	0.09	0.20	0.08	0.41	6.55	6.55

Colum Sum	1.92	0.75	1.52	0.49	1.10	0.44	2.18	
Specf Consumpt	1.92	0.75	1.52	0.49	1.10	0.44	2.19	(2.27 c)

For 2005

	0.31	0.30	0.48	0.10	0.08	0.15	0.68	0.23	1.46	0.25	0.14	0.24
	0.30	0.30	0.48	0.10	0.08	0.15	0.68	0.23	1.45	0.25	0.14	0.24
	0.07	0.07	0.11	0.02	0.02	0.03	0.16	0.05	0.33	0.06	0.03	0.05
Tij =	0.29	1.27	2.04	0.41	0.34	0.62	1.28	0.96	6.17	1.05	0.57	1.00
	0.43	0.42	0.68	0.14	0.11	0.21	0.49	0.32	2.06	0.25	0.19	0.33

Colum Sum	2.39	2.35	3.79	0.76	0.64	1.15	2.29	1.79	11.49	1.96	1.07	1.88
Specf Conspt.	2.39	2.35	3.79	077	0.64	1.15	2.29	1.79	11.50	1.96	1.07	1.88

							Row Sum	Specf. Production
0.29	0.11	0.23	0.07	0.16	0.07	0.33	5.26	5.26
0.29	0.11	0.23	0.07	0.16	0.07	0.33	5.26	5.26
0.06	0.02	0.05	0.02	0.04	0.01	0.07	1.17	1.17
1.21	0.47	0.995	0.31	0.69	0.28	1.37	22.17	22.17
0.40	0.16	0.32	0.10	0.23	0.09	0.46	7.39	7.39

Colum Sum	2.24	0.88	1.77	0.57	1.28	0.51	2.55	
Specf Con.	2.24	0.88	1.77	0.57	1.28	0.51	2.56	.............(2.27 d)

One may then apply the Gravity model of eqn. 2.19 and eqn. 2.20 and obtain estimates of t^{m}_{ij} for future years. The estimates of flow for 1990,1995, 2000 and 2005are given in the T^{m}_{ij} – matrix forms as shown in eqn. (2.27.a.b.c.d). It is observed that the estimates obtained on the basis of the Export Model are somewhat different in comparison with those obtained using the production – consumption model (eqn. 2.22 and eqn. 2.23). These differences might essentially be attributed to different typology of models used (Paul C Njoku 2003)

6.0 CONCLUSION.

A gravity model of transport flow appears to provide a useful technique which gives rise to improved interzonal flow estimates when one or the other kind of constraint is put on the flow pattern. It appears that this technique has been applied for the first time to the Nigerian situation with regard to petroleum product distribution among its states. This study should help generate more of such studies so that large and complex public utility systems may be planned on sound scientific basis.

While dealing with a relatively simple problem of inter regional commodity flow distribution such as the one considered in this book, one would tend to think that perhaps linear programming (LP) technique as well might be able to give the required flows. However, one must remember that a LP Model is normative in nature and may not be able to describe a real life situation as well. It is known that the gravity model is a descriptive systems technique, which strives to represent as closely as possible the system in its characterized form rather than prescribing norms for its behaviour as the linear programming model would tend to do.

TABLE 1

PETROLEUM CONSUMPTION DEMAND AND CRUDE OIL PROJECTION (PROFILE)

	1979	1980	1981	1982	1983	1984	1990	1995	2000	2005
PETROLEUM CONSPT.. IN MT DEMAND	10.1	11.9	12.9	14.11	15.29	16.47	23.35	29.45	35.34	41.2
CRUDE OIL PRODUCTION IN MT	112.5	99.12	69.15	61.81	71.19	66.54	134.6	154.2	175.7	197

Note 36 British Imperial Gallons of liquid oil is equal to one barrel of British Imperial Gallon is equal to 4.541 litres. Average Nigerian specific Gravity of crude oil has an ATP value of 0.8191. Therefore 1 Barrel of oil - 36. 541 x 0. 81991 kg = 133. 903kg

Report: Source: Nigerian Petroleum Corporation Statistics

TABLE 2

PRODUCTION CELING AND QUOTA ALLOCATIONS TO OPEC MEMBER COUNTRIES.

Country	Quota MBD	Country	Quota MBD
Algeria	663,000	Ecuador	183,000
Gabon	137,000	Indonesia	1,189,000
Lan	2,300,000	Iraq	1,200,000
Kuwait	900,000	Libya	990,000
Nigeria	1,300,000	Qatar	280,000
Saudi Arabia	4,353,000	UAE	950,000
Venezuela	1,555,000		
Total 16,000,000 MBD			

Source: Ordinary Meeting of OPEC Brioni Yugoslavia 1986

TABLE 3

TOTAL INVESTMENT IN EXPLORATION AND PRODUCTION OF OIL MILLION NAIRA

1972	1973	1974	1976	1977	1978	1979	1980	1981	1982	1983
178	643	724	733	971.7	337.8	1104.0	1084.0	1516.0	1206.0	787.0

Source: NNPC Budget Unit, Cooperation Planning Department Lagos

TABLE 4

CAPACITIES OF MAJOR PROCESSING UNITS INNIGERIAN REFINERIES

Company: NNPC Location	Project type	Capacity b/d	Remarks on Status
Cross Rivers State	New Refinery	100,000	Request for EPC bids pending
Kaduna	Crude	100,000 unit 1,110,000	Expansion to 50,000b/d crude to total capacity of units 1&2 Chiyode 1986
PortHarcourt	New Refinery	100,000	EPC bids out, evaluation started
Warri	Crude	25,000 Snamprogetti	125,000 total capacity all 1985 on all units
	vacuum	4,000	36,000 total capacity
	FCC	1,000	27,000 total capacity
	Reform	300	17,000 total capcity
	Hydro treat	300	17,000 total capacity
	Alkylation	3,000	Lummus Crest 1985

Source: Oil and Gas Journal Report October, 29,1984, OGJP. 93
Designates Projects listed for the first time in Journal

TABLE 5

DATA FOR COMPUTING GRAVITY MODEL BASED PP FLOW

STATES	CONSUMP OF PP IN MT					DISTANCE IN KM FROM				
	1990		1995	2000	2005	KR	PR	WR	P	W
Kaduna	1.366	1.709	2.051	2.393	149.5	6.36	606	6.38	609	
Rivers/Bayelsa	1.343	1.679	2.051	2.351	696	83	189	83	189	
Bendel/Edo/Delta	2.159	2.639	3.231	3.771	609	904	90	904	90	
Sokoto/Kebbi/Zamfara	0.435	0.546	0.656	0.765	433	1164	1039	1164	1939	
Niger/Abuja	0.363		0.455	0546	0.637	270	532	540	532	540
Kwara/Kogi	0.654		0.818	0.982	1.146	405	98	596	98	596
Oyo	1.249	1.562	1.875	2.188	540	879	491	879	491	
Ogun	1.025	1.281	1.537	1.794	675	946	423	946	423	
Lagos	6.564	0.209	9.851	11.495	648	850	396	850	396	
Ondo/Osun/Ekiti	1.118	1.398	1.678	1.958	594	1188	206	1188	206	
Cross River/Akwa Ibom	0.609	0.761	0.914	1.066	690	135	324	135	324	
Imo/Abia/Ebonyi	1.057	1.322	1.586	1,851	540	135	324	135	324	
Anambra/Enugu	1.280	1.600	1.921	2.241	405	204	393	204	393	
Benue	0.499	0.624	0.749	0.875	486	285	382	285	382	
Plateau/Nassarawa	1.013	1.266	1,520	1.774	324	609	798	609	798	
Gongola/Taraba/Adamawa	0.325	0.406	0.488	0.569	737	879	1048	879	1068	
Borno/Yobe	0.731	0.914	0.097	1.280	718	1327	1516	1327	1516	
Bauchi/Gombe	0.293	0.366	0.440	0.513	300	945	1138	945	1138	
Kano/Jigawa/Katsina		1.460	1.826	2.191	2.557	222	858	828	858	828

TABLE 6a

REGRESSION MODEL ESTIMATEs: TABLE 6b EXPORT MODEL

: ESTIMATES
: PP: PRODUCTION IN MT:PP: IMPORT IN MT

	KR	PR	WR	P	W	KR	PR	WR	PP	W
1990	3.522	3.582	0.796	11.69	3.89	2.545	2.545	0.561	14.46	4.46
1995	4.162	4.162	0.925	15.15	5.05	3.225	3.225	0.717	16.71	5.57
2000	4.743	4.743	1.054	18.6	6.2	4.117	4.117	0.915	19.64	6.54
2005	5,323	5,323	1.183	22.05	7.35	5.256	5.256	1.168	22.17	7.3

PP Petroleum Production, KR: Kaduna Refinery, PR: PortHarcourt Refinery, WR Warri Refinery, P: PortHarcourt Port, W: Warri Port, Mt: Million Tones, KM Kilometre.

TABLE 7

NIGERIA OIL IMPORTS 000 BARRELS PER DAY AS PERCENT TOTAL PRODUCTION

	1973	1978	1982	1983
Oil Import 000 barl.	448,458	8221,126	514,00	292.000
Oil Import	(13.82)	(12.54)	(10.0)	(5.9)

Source: Nigerian National Petroleum Corporation Lagos.

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