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Regulating Oil Price Using Transportation Model and Transportation Algorithm

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Abstract *- Crude oil remains a cornerstone of many national economies, such as Nigeria's. Like most commodities, the economic forces of supply and demand determine the price per barrel of crude oil. An increase in demand without a corresponding increase in supply will lead to inflation in oil prices; conversely, a decrease in demand without a corresponding decrease in supply will cause price of the product to fall drastically. These extremes are detrimental to any economy. To avoid such fluctuations, regulating the price of crude oil is essential. The transportation model, a tool in operations research, helps determine the quantities of a particular item to be distributed from various sources to various destinations, with the goal of minimizing distribution costs. This model is based on the economic concepts of demand, supply, and equilibrium price. Balancing the traditional transportation model requires introducing new supply or demand at zero-unit cost. However, since it is not feasible to introduce new markets (demand) or new producers (supply), this paper presents a novel proportional method for balancing the transportation model among suppliers and consumers of crude oil. Using an appropriate transportation algorithm, the paper determines the quantities of crude oil that exporting countries will supply to various importing countries. Statistical data from OPEC illustrates the proportional approach to balancing the transportation model, and the transportation algorithm is applied to identify the optimum quantities to be supplied from producing to consuming countries.*
Keywords*- Crude oil, demand, supply, equilibrium, economic theory, operation research, transportation model, transportation problem, transportation algorithm, balancing transportation model;*

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I. Introduction

It has been reported that one of the challenges facing OPEC is the fluctuation of oil revenue, which results from changes in the demand and supply of oil,[11]. Member countries have adopted various strategies to address this problem, primarily focusing on increasing supply when demand rises and decreasing supply when demand falls. Determining the exact supply figures for each OPEC member country in response to fluctuations in oil demand is a challenge best addressed by the transportation model.

The transportation model is a classical Operations Research framework that represents both producers or suppliers of an item and the consumers or demanders of that item. It also accounts for the cost per unit of transporting the item from various sources to various destinations. The transportation problem is defined as determining the quantities of the item to be distributed from various sources to various destinations, with the goal of minimizing distribution costs. This problem seeks to minimize total transportation costs while satisfying demand and supply constraints across the sources and destinations,[12]. The transportation algorithm, based on the simplex algorithm, provides a solution to this problem. One of its major assumptions is that total supply must equal total demand. This implies that the algorithm is grounded in the economic theories of demand, supply, and equilibrium price, which can help stabilize the oil market by preventing extreme fluctuations in oil prices.

The transportation model can be applied to determining the quantities of crude oil that producing countries will supply to consuming countries, with the goal of minimizing supply costs. By applying the economic theories of demand, supply, and equilibrium to the results of the transportation algorithm, stability in the oil market can be achieved, mitigating the extremes of inflation or drastic price drops.

The transportation model is represented as a two-dimensional table, where rows correspond to various producers or suppliers, and columns represent consumers or destinations. The intersections of these rows and columns create cells that define the cost of transporting one barrel of oil from a specific source to a specific destination. The transportation problem entails determining the quantity of oil associated with each cell, indicating the amount to be transported from a source to a destination. Each row also indicates the total amount a particular source is willing to supply, while each column indicates the total demand from a destination.

Table 1 illustrates this model, showing three producers/exporters (labeled as countries A, B, and C) and three consumers/importers (labeled as countries 1, 2, and 3). For each exporter/supplier, the last column indicates the total barrels of oil that the country will supply, while the last row for each consuming country shows its total demand. In this model, Cij denotes the cost of transporting one barrel of oil from country i to countryj, while Xij is the amount of oil that country i will supply to countryj. The transportation problem aims to determine Xij that minimizes total transportation costs. While the transportation model enhances operational efficiency, external factors such as market dynamics and speculation also play significant roles in determining crude oil prices, indicating that a holistic approach is necessary for effective demand and supply management.

The economic forces of demand, supply, and equilibrium price can utilize the results of the transportation problem to regulate oil prices. Whenever there is a change in demand, the transportation algorithm will respond with an appropriate adjustment in supply. Figure 1 further illustrates this concept.

The number of barrels of oil supplied by producing countries is a strategic issue whenever crude oil prices fluctuate. Therefore, the Organization of the Petroleum Exporting Countries (OPEC) needs to consider long-term measures for regulating oil prices. Effective regulation should be supported by techniques such as the transportation model, which is useful for exploring alternative ways of stabilizing oil prices. This model is founded on the economic concepts of demand, supply, and equilibrium,[4, 8, 9]. Previous studies have noted that supply, demand, and price are fundamental elements in any market,[5, 6, 7]. Although regulating oil prices differs from forecasting them, the two are closely related; understanding oil price forecasts can inform regulatory measures to maintain acceptable price levels. OPEC has traditionally used the OPEC Reference Basket (ORB) to forecast oil prices, [1].

While some reports have presented short-term regulatory measures in response to fluctuating oil prices, [1], they have also emphasized that long-term regulatory strategies depend on market forces of demand and supply. Regarding price control, it has been pointed out that government-imposed price fixing can lead to significant problems, [2], indicating that allowing market forces to dictate prices is generally preferable. When prices are set below the equilibrium level, consumers tend to demand more than producers can supply, resulting in scarcity. This dynamic interaction between supply and demand is foundational to economics, producing an equilibrium market price where the quantity demanded by consumers equals the quantity supplied by sellers. A unified framework for computing equilibria has been applied in mathematical programming models involving government policies that affect market prices, [3].

Similar to this study, previous research has formulated the transportation model as a linear programming problem and applied it to the crude oil industry by solving the oil tanker routing problem, [13]. However, none have explored how the transportation problem can specifically be used to regulate crude oil prices. Therefore, evidence suggests that no study has yet utilized the transportation model to address the regulation of crude oil prices effectively.

Table 1: The transportation Model

	1	2	3	Supply
A	C_{11} X_{11}	C_{12}	X_{13} C_{13}	$\sum_{j=1}^{3} X_{1j}$
B	X_{21} C_{21}	X_{22} C_{22}	X_{23} C_{23}	$\sum_{j=1}^{3} X_{2j}$
C	X_{31} C_{31}	X_{32} C_{32}	X_{33} C_{33}	$\sum_{j=1}^{3} X_{3j}$
Demand	$\sum_{i=1}^{3} X_{i1}$	$\sum_{i=1}^{3} X_{i2}$	$\sum_{i=1}^{3} X_{i3}$	$\sum_{i=1}^{3}\left(\sum_{j=1}^{3} X_{ij}\right) = \sum_{j=1}^{3}\left(\sum_{ij=1}^{3} X_{ij}\right)$

Figure 1 illustrates how the economic theories of demand, supply, and equilibrium price can utilize the results of the transportation model to determine an appropriate equilibrium price for regulating oil prices. An increase in the demand curve from D1 to D2 necessitates a corresponding increase in the supply curve from S1 to

S2. Similarly, a decrease in the demand curve from D2 to D1 requires a corresponding decrease in the supply curve from S2 to S1. These adjustments in supply in response to changes in demand help regulate and stabilize oil prices.

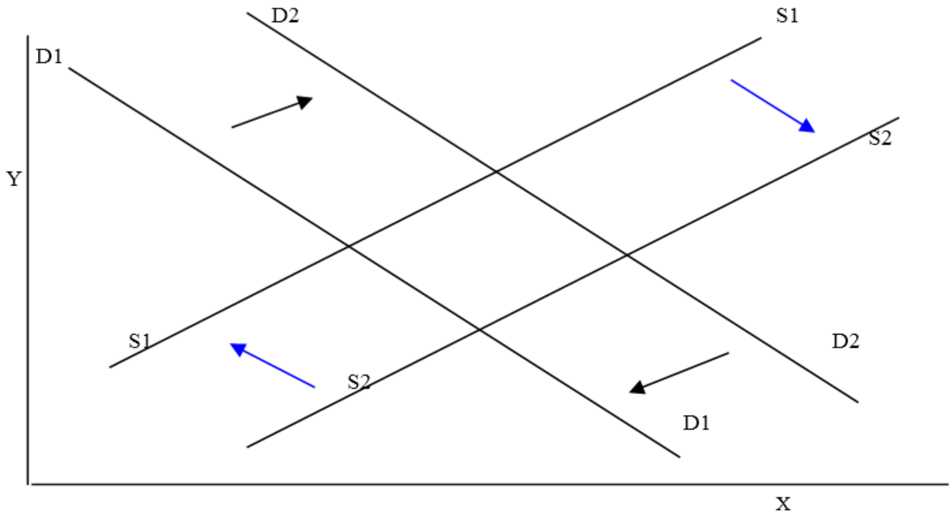

Figure 1: Economic Theory of Demand, Supply and Equilibrium Price

Therefore, the significant contribution of this paper is two-fold, which include the application of transportation model and transportation algorithm in regulating crude oil price, and the use of proportional method in balancing the transportation model.

II. Material and Methods

Five oil-exporting countries and three oil-importing countries were sampled from [1]. Each oil-exporting country can export to any of the oil-importing countries. Table 2 presents the balanced transportation model, where Cij represents the cost of transporting one barrel of oil from country i to country j. Xij denotes the number of barrels of oil, which the transportation algorithm determines; it represents the quantity of oil that country i will export to country j with the goal of minimizing transportation costs.

TABLE 2 TRANSPORTATION MODEL FOR THE OIL MARKET

	Canada	Brazil	Bulgaria	Supply
USA	X_{11} C_{11}	X_{12} C_{12}	X_{13} C_{13}	S_1
Venuzuela	X_{21} C_{21}	X_{22} C_{22}	X_{23} C_{23}	S_2
Russia	X_{31} C_{31}	X_{32} C_{32}	X_{33} C_{33}	S_3
UK	X_{41} C_{41}	X_{42} C_{42}	X_{43} C_{43}	S_4
Nigeria	X_{51} C_{51}	X_{52} C_{52}	X_{53} C_{53}	S_5
Demand	D_1	D_2	D_3	$\sum_{i=1}^{5} S_i = \sum_{j=1}^{3} D_i$

As stated earlier, one of the assumptions of the transportation model is that total demand must equal total supply; this is the equilibrium assumption. If this assumption does not hold in the transportation model, the novel proportional method of balancing the transportation model will apply. Balancing a transportation model involves making total demand equal to total supply. If total demand exceeds total supply, the difference will be proportionally added to the suppliers based on their respective supplies. Conversely, if total supply exceeds total demand, the difference will be proportionally subtracted from the suppliers based on their total supplies.
Different versions of the transportation algorithm exist, all, based on the simplex method. This paper will present the Vogel Approximation Method, [14].

Step 1

This step, similar to the simplex method, determines the initial solution of the basic variables. The minor steps are as follows:

Step1.1

For each row and column of the balanced transportation model, calculate the row and column penalties. The row penalty is the difference between the smallest unit cost and the next smallest unit cost in each row. Conversely, the column penalty is the difference between the smallest unit cost and the next smallest unit cost in each column.

Step 1.2

Identify the row or column with the highest penalty.

Step 1.3

In the row or column with the highest penalty, allocate as much as possible to the cell with the smallest unit cost, aiming to satisfy both demand and supply. Cross out the row or column that has been satisfied as a result of this allocation. Only one row or one column should be crossed out at any given time.

Step 1.4

Repeat Steps 1.1, 1.2, and 1.3 until all rows and columns have been allocated and crossed out. However, if only one row or one column with non-zero demand or supply remains, use the method of least cost to allocate as much as possible to the cell with the least cost per unit. If the row or column has zero supply or demand, stop. If there are multiple rows or columns with zero supply or demand, use the method of least cost to determine the basic zero variable.

Step 2

Perform the simplex optimality test to identify the entering variable.

Step 2.1

For each row and column, determine the values of the multipliers Uiand Vj, which must satisfy the condition $U_i+V_j = C_{ij}$, for each basic variable Xij. First, assign an arbitrary value of 0 to the U1 multiplier to calculate the other multiplier values.

Step 2.2

For each non-basic variable, calculate the value of the expression $U_i + V_j – C_{ij}$.

Step 2.3

Among the values calculated in Step 2.2 for the non-basic variable Xij, identify the highest positive value, which will become the entering variable. If no positive value exists, the simplex optimality test has been satisfied, indicating that there is no entering or leaving variables, and the algorithm stops. However, if an entering variable exists, proceed to Step 3.

Step 3

Perform the simplex feasibility test to identify the leaving variable.

Step 3.1

Starting at the entering variable cell, form a closed loop by moving horizontally and vertically; each corner or vertex of the loop must be one of the basic variable cells.

Step 3.2

Beginning at the entering variable cell, alternately add and subtract α at each corner or vertex of the closed loop.

Step 3.3

Determine the maximum value of α that will reduce one of the basic variables at a corner of the loop to zero. This basic variable will be the leaving variable. Note that the non-negativity condition must be maintained.

Step 3.4
Adjust the values of Xij for the basic variables as a result of the addition and subtraction of, α, alphaα.
Step 3.5
Repeat Step 2.

2.1 Using Simplex Algorithm to Solve Transportation Problem

The simplex algorithm, which solves linear programming problems, can be applied to the transportation problem. To use this method, the transportation problem must first be reformulated as a linear programming problem. After this reformulation, the simplex method can be employed to find a solution. The result obtained from the simplex method will be equivalent to that derived from the transportation algorithm. However, one important assumption is that the basic variables in the transportation model have already been established. The transportation problem presented in Table 2 can be reformulated as a linear programming problem as shown in Equation (1).

$$\text{Minimize } Z = \sum_{i=1}^{5}\left(\sum_{j=1}^{3} C_{ij} X_{ij}\right) \quad (1)$$

Subject to:

$$\sum_{j=1}^{3} X_{1j} = S_1$$

$$\sum_{j=1}^{3} X_{2j} = S_2$$

$$\sum_{j=1}^{3} X_{3j} = S_3$$

$$\sum_{j=1}^{3} X_{4j} = S_4$$

$$\sum_{j=1}^{3} X_{5j} = S_5$$

$$\sum_{i=1}^{5} X_{i1} = D_1$$

$$\sum_{i=1}^{5} X_{i2} = D_2$$

$$\sum_{i=1}^{5} X_{i3} = D_3$$

$$Xij \geq 0 \forall i, j$$

The following simplex algorithm steps can be used to determine the values of the basic variables:

Step 1: Form the Initial Simplex Tableau
Arrange the coefficients of the linear programming problem in a tabular format to create the initial simplex tableau. The coefficients of the constraints will form the rows, while the coefficients of the objective function will comprise the z-row.

Step 2: Perform the Optimality Test to Select the Pivot Column
Identify the pivot column in the current tableau, which has not yet been selected. This column corresponds to the z-row element with the smallest value relative to the basic variables.

Step 3: Calculate the Value of Alpha
To determine the value of alpha for each row of the tableau, divide the solution column of each row by the corresponding element of the pivot column, excluding the z-row.

Step 4: Perform the Feasibility Test by Selecting the Pivot Row
The pivot row is the one with the smallest positive value of alpha, excluding zero. The pivot element is the intersection of the pivot row and the pivot column.
Step 5: Form One Row of the New Tableau
Create this row by dividing each element of the pivot row by the pivot element.
Step 6: Compute the Other Rows of the New Tableau
Follow these sub-steps to update the rows:
1. Write the old element.
2. Write the pivot column element for that row.
3. Write the row obtained in Step 5.
4. Multiply the elements from Steps 6.2 and 6.3.
5. Calculate the new row element as follows: Row element = Step 6.1 - Step 6.4.

Step 7: Repeat Steps 2, 3, 4, 5, and 6
Continue this process until all columns of the basic variables have been selected as the pivot column.

III. Results and Discussion of Results

Table 3 presents the cost of transporting one barrel of oil from three oil-producing countries to four oil-consuming countries, along with the total supply from the producing countries and the total demand from the consuming countries. Suppose there is a decrease in the demand for oil, resulting in supply exceeding demand, as shown in Table 1.

Table 4. Cost of Transporting One Barrel of Oil

	1	2	3	4	Supply
1	2500	3750	5000	3500	400
2	1250	1750	1500	1625	200
3	1000	2750	2500	3750	150
Demand	100	200	150	160	

The proportional approach will be used to balance the transportation model, and the transportation algorithm will determine the quantities of barrels of oil to be transported from the various producing countries to the consuming countries, as detailed in Table 4.

Table 4. Balanced Transportation Model.

	1	2	3	4	Supply
1	2500 X_{11}	3750 X_{12}	5000 X_{13}	3500 X_{14}	325
2	1250 X_{21}	1750 X_{22}	1500 X_{23}	1625 X_{24}	163
3	1000 X_{31}	2750 X_{32}	2500 X_{33}	3750 X_{34}	122
Demand	100	200	150	160	610

Tables 5, 6, 7, and 8 display the results obtained from the first, second, third, and fourth iterations of the transportation algorithm.

Table 5. Table for the Initial Solution

	1 V1=3500	2 V2=3750	3 V3=5000	4 V4=\5125	Supply
1 U1=0	2500 1000	3750 200	5000 125	3500 1625	325
2 U2=-3500	1250 -1250	1750 -1500	1500 3	1625 160	163
3 U3=-2500	1000 100	2750 -1500	2500 22	3750 - 1125	122
Demand	100	200	150	160	610

Table 6. Table for the First Iteration of the Algorithm.

	1 V1=1875	2 V2=3750	3 V3=3375	4 V4=3500	Supply
1 U1=0	2500 -625	3750 200	5000 -1625	3500 125	325
2 U2=-1875	1250 -1250	1750 125	1500 128	1625 35	163
3 U3=-875	1000 100	2750 125	2500 22	3750 -1125	122
Demand	100	200	150	160	610

Table 7. Table for the Second Iteration of the Algorithm.

	1 V1=2000	2 V2=3750	3 V3=3375	4 V4=\3500	Supply
1 U1=0	2500 -500	3750 178	5000 -1625	3500 147	325
2 U2=-875	1250 -125	1750 125	1500 150	1625 13	163
3 U3=-1000	1000 100	2750 22	2500 -1225	3750 -1250	122
Demand	100	200	150	160	610

Table 8. Table for the Third Iteration of the Algorithm.

	1 V1=2000	2 V2=3750	3 V3=3500	4 V4=3500	Supply
1 U1=0	2500 -500	3750 165	5000 -1500	3500 160	325
2 U2=-2000	1250 -1250	1750 13	1500 150	1625 -125	163
3 U3=-1000	1000 100	2750 22	2500 0	3750 -1200	122
Demand	100	200	150	160	610

Table 8 shows the optimal barrel of crude oil, which will be transported from the various sources to the various destinations, in response to the change in demand. It shows that supplier/exporter/source/country 1 will distribute 0, 165, 0, and 160 barrels of crude oil to consumer/importer/destination/country 1, 2, 3, and 4, respectively. In a similar manner, supplier/exporter/source/country 2 will distribute 0, 13, 150, and 0 barrels of crude oil to consumer/importer/destination/country 1, 2, 3, and 4, respectively, while supplier/exporter/source/country 3 will distribute 100, 22, 0, and 0 barrels of crude oil to consumer/importer/destination/country 1, 2, 3, and 4, respectively. The transportation model and transportation algorithm have enabled us to determine the optimal barrel of oil that various oil-producing countries will produce. At time T0, the initial equilibrium price was P0, and the equilibrium quantity wasQ0, as shown in Figure 1. At time T1, a decline in demand has caused the equilibrium price to drop to P1, while the equilibrium quantity falls to Q1.

Although this situation is unfavorable, the transportation model and algorithm have assisted us in identifying the appropriate supply for the market. Supply has been reduced, leading to a new equilibrium price of P2 and a new equilibrium quantity of Q2. It is noteworthy that the price difference between P0 and P2 is relatively small compared to the difference between P0 and P1.

Additionally, the Java programming language can be utilized to implement the transportation algorithm, employing a two-dimensional array as the data structure.

IV. Conclusion

This paper successfully applies the transportation model to the oil market. It presents a novel approach to balancing an unbalanced oil transportation model and utilizes statistics from the OPEC statistical bulletin to formulate and solve an oil transportation problem. Future research will focus on implementing the transportation algorithm using relevant data structures and the Java programming language.

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