PRODUCTIVITY IMPLICATIONS OF ROBOTICS AND AUTOMATION

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ABSTRACT

Productivity is a very important consideration in any process like construction because it influences cost and output greatly. A firm creates wealth by combining resources from its domicile economy with resources from other economies. Resources derived from the domicile economy which enter the wealth creation process constitute 'internal participation' while those from other economies make up 'external participation'. Increased understanding of the production process enables the domicile economy to increase its participation with internally derived inputs. The result is increased output, lower unit cost and more profit for the firm. Therefore, the level of 'internal participation' in the creation of wealth determines how productive an individual, society or nation is.

Higher 'internal participation' in production generates greater productivity. However, output-per-unit-input is a measure of rate-of-performance not productivity. Increase in rate-of-performance is expansion which is not synonymous with productivity improvement. Actually, expansion can occur while productivity is declining. Consequently the firm's viability diminishes.

An indepth analysis of robotics and automation with the 'Develonic Approach' is necessary to reveal their productivity impact on the construction. It is not economically wise for a firm to embark on widespread automation and robotics if such a step reduces 'internal participation' in production.

1. INTRODUCTION

The conventional definition and measurement of productivity seem to ignore the impact of the level of development in the production technology which often result in inaccurate conclusions. This paper presents a more practical and accurate method of determining productivity.

2. DEVELONIC EQUATION

To understand the inter-relationship between productivity, technology, cost and output, the "DEVELONIC APPROACH" has to be introduced. The focal point of the Develonic approach is the DEVELONIC EQUATION (See Reference 1). It is an empirical, pictorial display of how any firm, industry or economy is producing goods and services (wealth) at any given time. Production includes all processes and activities leading to the creation and delivering of goods or services to the ultimate consumer. A firm creates wealth by combining resources from its domicile economy with resources from other economies. At a glance, the develonic

equation shows the levels of employment, development, income and productivity of the domicile economy in the production process (See Reference 6). The equation applies to any type of economy (capitalist, socialist, communist, planned, market or mixed) without bias. To obtain the equation, the economy's participations or contributions in all factors of production are translated into monetary values and summed up. The value of the sum of the economy's participations is then expressed as a percentage of the total cost of production. An example of a den. An example of a develonic eqation is:

Production = 20% (I) + 80% (E) ----------(1)
Where
'I' = Internal contribution from the economy
'E' = External contribution to the economy

Eq.1 states that 20% of the resources needed in the production process is obtained from within the economy where the production is taking place while the remaining 80% of the needed resources is obtained from other economies. It should be noted that Eq.1 is a dimensionless ratio expression. Its units are determined by the units of the analysis which is being done. For example, if the unit cost of Eq.1 production is $100 then, $20 worth of resources come from within the economy while $80 worth of resources is imported. Alternatively, if 100 man-hours (m-hr) are needed in Eq.1 to produce one unit of output then, 20 m-hrs are obtained from the economy while 80 m-hrs are hired from other economies. In order words, if the production requires only human work-force of 100 workers, only 20 workers would be required from within the economy.

There are two parts of the develonic equation namely:- Internally and Externally derived parts. Resources from the economy where the production is taking place are termed "INTERNAL PARTICIPATION" while resources from other economies which enter the production process are called "EXTERNAL PARTICIPATION". "Internal Participation" is a potential income for the economy because payment for it merely relocates wealth within the economy. However, "External Participation" is a potential cost to the economy because payment for it involves transfer of wealth out of the economy. No production or wealth creation can take place unless the two parts are available because production is a COMBINATION and NOT a COLLECTION of inputs (See Reference 2). Both parts are necessary but neither part alone is sufficient for the creation of the wealth. Both parts combine to produce the whole good or service. Therefore, the sum of the internaal and external parts must always equal unity. The develonic equation is expressed generally as:

$$x + y = 1 \qquad \text{----------(2)}$$

Where
x = internal participation
y = external participation

3. DEVELONIC PYRAMID

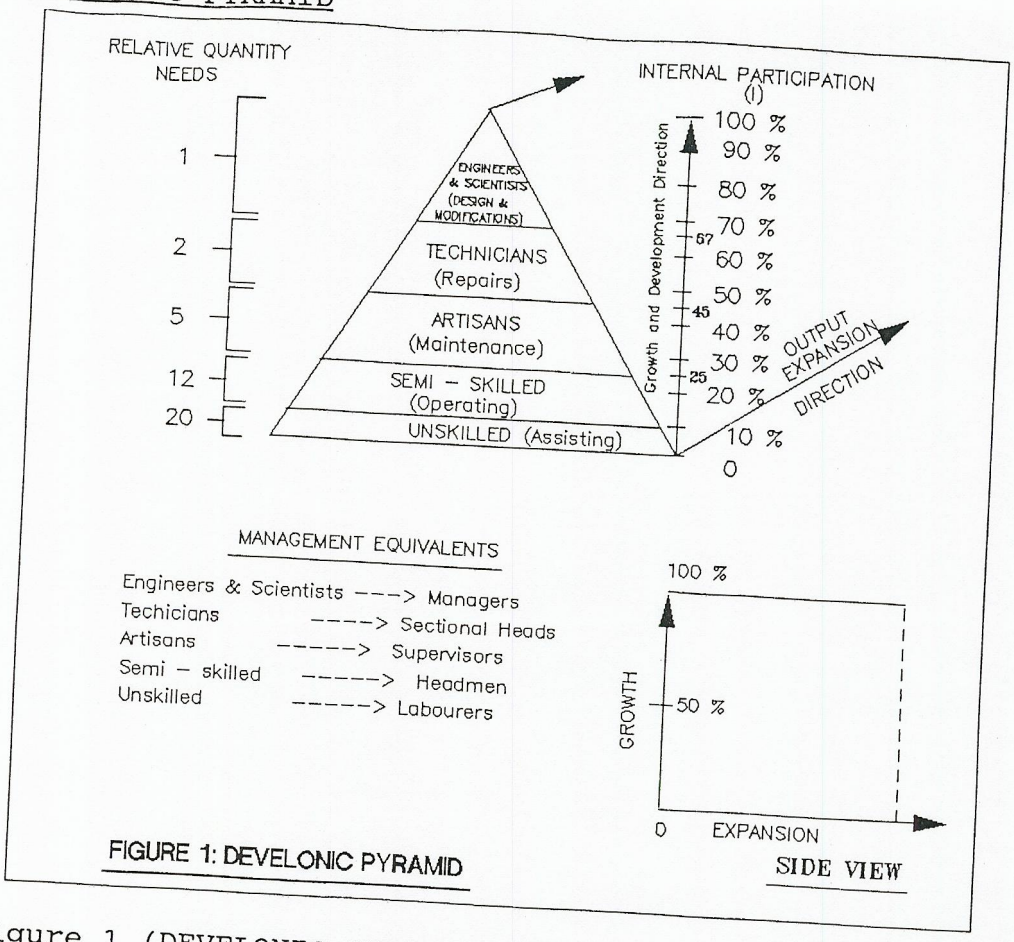

FIGURE 1: DEVELONIC PYRAMID

Figure 1 (DEVELONIC PYRAMID) (DP) is a representation of the hierarchy of generalized inputs for a unit output in a production process (See Reference 1 for its background). It elaborates some of the useful pieces of information which are embodied in the develonic equation. The percentage contribution to production is based on the quality of the input which is reflected in the cost (payment) of such input. The pyramid shape indicates the decreasing quantity required as the quality of the input increases which also attracts higher cost (payment) per unit of the input. Brief explanations of what the generalized inputs represent are as follows:

'UNSKILLED': Unskilled labour, land, materials in their very raw nature and other inputs that merely assist in production.
'SEMI-SKILLED': Semi-skilled labour, industrial raw materials and other inputs that operate the production process.
'ARTISANS': Artisan labour, equipment maintenance materials and other inputs that maintain the production process.
'TECHNICIANS': Technician labour, equipment and parts and other inputs that effect repairs to the production facilities.
'ENGINEERS & SCIENTISTS': Engineer and Scientist's labour, and other inputs that design or modify the production process.

The "Relative Quantity Needs" in Figure 1 implies that for example, if an economy develops to produce one "engineer" in the production process, it would generate jobs for 2 "technicians", 5 "artisans", 12 "semi-skilled" and 20 "unskilled". If the economy develops to produce one "artisan" in the production process, then

jobs for about 2 "semi-skilled" and 4 "unskilled" would be generated. In the same manner if the economy deteriorates through lack of participation and loses the ability to produce say an 'artisan' which it was formerly producing, then about 2 'semi-skilled' and 4 'unskilled' would become redundant as well. DP is a kind of 'guage' which could be used to quickly evaluate different possible technologies for a given production or the direction of growth and development in a given technology for a production process. As an economy understand more about the technology of the production process it becomes more aware (mor developed or experienced) and is able to increase its internal participation and growth takes place. The quality of the economy's output also improves. If an economy's internal inputs into a production process are only 'unskilled' and 'semi-skilled' (25%) then, the economy could be said to be under-developed in the production technology. An economy that achieves at least 67% internal participation can be said to be developed in the given production technology. For a detailed discussion on the explicit classification of economies into developed, developing and under-developed See Reference 1. The D.P. explains why a naturally endowed country like Nigeria could be poor while another relatively much less naturally endowed country is very rich. It should be noted that the actual roles played by inputs in production are what determine their placings in D.P. not their potential roles. Movement from one position in the hierarchy to another is based on experience in the production process. The reader should see Reference 3 for the use of Figure 1 in explaining the differences between Growth and Expansion.

4. PORODUCTIVITIY, TECHNOLOGY AND OUTPUT

Given a technology and a level of development in the technology, an economy could not produce a good or service more efficiently thqt what its develonic equation for the good or service portrays. Technology includes the technical, management, distributive and marketing activities of production. The production of most modern goods and services in an economy is not possible until BOTH internal inputs (internal participation) and external inputs (external participation) are available.

The develonic equation proveds a theoretical and practical method of determining the productivity in an economy in a given good or service while taking into account the level of development of the economy in the available technology and techniques. Variations of the quantities of all inputs in the production process are handled simultaneously. The objective is to determine, for given resources, the best inputs ratio that would generate the best benefits by yielding the greatest output and the lowest unit price for the good or service. The benefits include more and better employment, increased income and better quality of life through improved development. Larger output-rate or bigger plant in a production process is not necessarily more efficient or more beneficial unless it yields lower unit cost goods or services with a given amount of resources at the increased output. The "Develonic Approach" or "DEVELONICS" takes the same sample from all possible production processes and analyses it for resource utilization and overall cost with the develonic equation in order to determine the most efficient process. The sample is usually the unit of the given good or

service. To demonstrate the theoretical relationship between productivity, technology and output, the following proof has been reproduced from Reference 3 Appendix.

4.1 Optimal Production

In order to show the impact of internal participation (level of technological development) on the production process, it is necessary to use two economies. Let us assume that the world has only two nations - Nations A and B. Each nation obtains its external participation in production from the other nation. A particular good or service is to be produced with a given technology. Let 'Ƶ' represent the total unit cost of the good or service. Therefore, the develonic equations and total unit costs of the good or service in both nations are:

$x_1 + y_1 = 1$, $Ƶ_1$ for Nation A ---------- (3)
$x_2 + y_2 = 1$, $Ƶ_2$ for Nation B ---------- (4)

4.1.1 Productivity Ratio

Total production value of output is equal to the total cost of production. The total unit output of the good is not entirely produced by the nation where the production is taking place. This is because, the external participation in production are necessary resources which must be obtained from the other nation in order that production can take place with the given technology. Therefore, the portion of the unit good that is produced by the nation where production is taking place is represented by the internal participation in the production.

For Nation A

$Ƶ_1 = x_1 Ƶ_1 + y_1 Ƶ_1$ = Total unit output
Nation A actual production (ie share of the output) = $x_1 Ƶ_1$ --(5)

For Nation B

$Ƶ_2 = x_2 Ƶ_2 + y_2 Ƶ_2$
Nation B actual production (ie share of the output) = $x_2 Ƶ_2$ --(6)
When equal resources are given to both nations.

$$\frac{\text{Actual Production of Nation B}}{\text{Actual Production of Nation A}} = \frac{\text{Productivity of Nation B}}{\text{Productivity of Nation A}} \text{ --(7)}$$

Let 'n' be the productivity ratio of Nation B to Nation A, Substituting for actual production in Eq.7 with Eqs.5 and 6.

$$\therefore \frac{\text{Productivity of Nation B}}{\text{Productivity of Nation A}} = \frac{x_2 Ƶ_2}{x_1 Ƶ_1} = n \text{ ---------- (8)}$$

Eq.8 says that, given equal resources, Nation B produces 'n' times the number of output units that Nation A produces.

4.1.2 Relative Output Cost

For simplicity, we shall assume that all production inputs are labour units. In order words, Nation A uses x_1 local labour units along with y_1 labour units from Nation B for one unit good production. Nation B uses x_2 local labour units along with y_2 labour units from Nation A to produce one unit good.

In a competitive environment like most production processes, labour is paid according to its level of participation or productivity (See Reference 1 and Figure 1). Therefore, the ratio of labour rates should be equal to the productivity ratio. That is, if labour rate in Nation A is 'R', then labour rate in Nation B will be 'nR'.

where $nR = n \times R$

Some observed envronmental influences on inputs need to be taken in to consideration. When labour, equipment or material migrates from one nation to another, it suffers what I would call "BLENDING EFFECT" which brings its productivity to approximately the same level with that of its new nation (environment) without changing its cost. Many workers from developing countries have been known to improve their productivity a great deal when they enter developed countries. However, workers from developed countries often suffer productivity decline in developing countries because of inadequate infrastructures and a tendency to "behave like the Romans while in Rome". Machines from developed countries generally do not perform as good in developing countries as they do in developed countries where they are produced due to indequate infrastructure, improper operation and poor maintenance. A barrel of oil will yield more useful by-products (more productive) in developed countries where refining is more developed than in developing countries where only a few by-products could be extracted.

The "Blending Effect" which changes the performance of the migrating production input has little or no impact on the cost of the input. The labour-rate for the worker, cost of the machine from a developed country and cost of a barrel of oil do not drop because their performances have dropped in the developing country. Likewise, the labour-rate for the worker from a developing country does not rise to that of a worker in the developed country where his performance has improved. Therefore, it is reasonable to assume that the labour-rate does not change for a worker from Nation A who works in Nation B, or vice versa although the "Blending Effect" has changed the worker's productivity. This means that the rate for labour from Nation A remains at 'R' while that for labour from Nation B remains at 'nR' regardless of which nation the labour is working in. Later, the impact of inequitable payments for inputs based on their productivity would be discussed during application of the derivations. However, the "Blending Effect" maintains the productivity ratio of Nation B to Nation A at 'n'.

Since all production inputs are assumed to be labour inputs,
Production cost = Labour units x labour-rate

$$\therefore \quad \text{Z}_1 = Rx_1 + nRy_1 \quad \text{for Nation A}$$
$$= R(x_1 + ny_1) \qquad \text{---------- (9)}$$

$$\text{Z}_2 = \frac{nRx_2 + Ry_2}{n} \quad \text{for Nation B}$$
$$= R(x_2 + \frac{y_2}{n}) \qquad \text{---------- (10)}$$

The expression for Z_2 reflects the fact that Nation B produces 'n' times the number of output units produced by Nation A when both nations are given equal resources.

From the nations' develonic equations: Eqs. 3 & 4.
$x_1 = 1-y_1$ from Nation A develonic equation
$x_2 = 1-y_2$ from Nation B develonic equation

substituting for x_1 and x_2 in Eqs. 9 and 10.

$$Z_1 = R\,(1-y_1 + ny_1)$$
$$= R[1 + y_1\,(n-1)] \quad \text{---------- (11)}$$

$$Z_2 = R\,(1-y_2 + \frac{y_2}{n})$$
$$= R[1-\frac{y_2}{n}\,(n-1)] \quad \text{---------- (12)}$$

A comparison of Eqs.11 and 12, shows that the only differences in the two expressions are the terms $(+y_1)$ in Eq.11 and $(-\frac{y_2}{n})$ in Eq.12. However, the following three general predictions can be deduced from Eqs,.8, 11 and 12.

i) If $x_2 > x_1$, Nation B in more developed in the production technology see Figure 1.

Then, $y_2 < y_1$ and $n > 1$
Therefore, $y_1 > \frac{y_2}{n}$
Hence $y_1(n-1) > \frac{y_2}{n}(n-1)$
and $Z_2 < Z_1$
Therefore Nation B is more productive

ii) If $x_2 = x_1$, Both Nations are at same level of development in the production technology

Then, $y_2 = y_1$ and $n = 1$
Therefore, $Z_2 = Z_1$
Both nations are equally productive

iii) If $x_2 < x_1$, Nation A is more developed in the production technology

Then, $y_2 > y_1$ and $n < 1$
Therefore, $Z_2 > Z_1$
Nation A is more productive

Predictions (i) and (iii) mean that a country that is more developed in the production technology will derive more benefits by producing more goods at lower total unit costs than the country that is less developed. More importantly, the predictions say that the less developed country may not be competitive with its produced good in its own market! They also indicate that for two firms operating in the same country, the firm with the higher internal participation in the production technology would generate more income and benefits by producing more competitive goods.

Prediction (ii) says that the only time to expect the total unit cost of a good and level of benefits to be the same in different countries or firms is when the level of development (internal participation) in the production technology is the same in each country or firm.

The predictions also establish the following defined relationships: (a) the quantity of output which is indicated by 'n' is directly functional with internal participation (x) (level of development); (b) the total cost of unit output (Ƶ) is directly functional with the external participation (y). It should be emphasized that the relationships are not linear (See Section 6). An increase in internal participation results in increase in productivity but not in the same proportion. The same is true for external participation and total cost of unit output.

It should be noted that the value of 'R' has insignificant impact on the predictions of the three equations if there is equitable payment for inputs based on their respective levels of participation (See Figure 1). Therefore, the system is effectively that of three equations with five unknowns. To obtain solutions, two unknowns must be chosen. The reader could verify the predictions which are stated above by choosing any two unknowns and solving for the other three. (Note: $0.0 \leq y_1 \leq 1.00$; $0.0 \leq x_1 \leq 1.0$; $0.0 \leq x_2 \leq 1.0$ and $0.0 \leq y_2 \leq 1.0$). To select the optimal production process for producing a particular good from a number of processes, one needs to estmate the 'Ƶ', 'x' and 'y' of each process. Using Eqs.8, 11 and 12 the most efficient and productive process would be selected.

5. PRODUCTIVITY

Economics often defines productivity as output per-unit-input with labour productivity predominating. This is an incomplete view of productivity because the crucial component of efficiency in generating the output has been ignored. For example, if distance covered is taken as the output, a driver who is doing 100 Kph (expanded output See Figure 1) is not necessarily more productive than one doing 60 Kph because fuel consumption per kilometer is higher at 100 Kph. Infact, with identical conditions, the 60 Kph car will cover greater distance (more productive) when both cars are given <u>equal amounts of fuel</u> (equal resources). Productivity has two components namely:- output and generation efficiency which translates to cost effectiveness. Its accurate determination must take <u>ALL</u> inputs simultaneously. This has been done in section 4 with the Develonic equation. Productivity is determined by the internal participation of an individual or economy in the production of wealth.

6. APPLICATION TO ROBOTICS AND AUTOMATION

Suppose a firm in a car industry of an economy is producing cars with the normal assembly-line technology and its develonic equation is determined to be

Car Manufacturing = 20% (I) + 80% (E) ---------- (13)

(The reader should see References 3,4 & 5 for a detailed develonic evaluation of the Nigerian Petroleum Industry performances in 1986 and 1988) The firm contemplates automating its car manufacturing process but the develonic equation would change to:

New Car Manufacturing = 10% (I) + 90% (E) ---------- (14)

Will the firm be more productive with automation?

6.1 Analysis

$x_{13} = 0.20$, $y_{13} = 0.80$; $x_{14} = 0.10$, $y_{14} = 0.90$

From Eqs. 11 & 12

$$\text{Ƶ}_{13} = R[1 + 0.80\ (n-1)] \quad \text{---------- (15)}$$

$$\text{Ƶ}_{14} = R\left[1-\frac{0.90}{n}\ (n-1)\right] \quad \text{---------- (16)}$$

From Eq. 8 and substituting for x_{13}, x_{14}, Ƶ_{13} and Ƶ_{14}

$$\frac{\text{Ƶ}_{14}}{\text{Ƶ}_{13}} = \frac{x_{13}n}{x_{14}} = \frac{0.20}{0.10}\,n = \frac{n-0.9(n-1)}{n[1 + 0.8\ (n-1)]}$$

$$\text{or } 2n = \frac{0.1n + 0.9}{0.2n + 0.8n^2}$$

$$\text{i.e } 1.6n^3 + 0.4n^2 - 0.1n - 0.9 = 0 \quad \text{---------- (17)}$$

Solution to Eq.17 is $n = 0.773$

Substituting for 'n' in Eqs. 15 and 16,

$$\text{Ƶ}_{13} = R[1 + 0.8\ (0.773-1)] = 0.818R$$

$$\text{Ƶ}_{14} = R\left[1-\frac{0.9}{0.773}\ (0.773-1)\right] = 1.264R$$

. . Eq.13 is more productive than Eq.14. This means that automation would make the firm less productive.

6.2 Economic Paradox

Suppose the automation shows that the firm's unit cost of production would be reduced even with Eq.14 i.e $\text{Ƶ}_{13} > \text{Ƶ}_{14}$

Then from Eq.8,

$$n = \frac{\text{Ƶ}_{14}x_{14}}{\text{Ƶ}_{13}x_{13}} = \frac{\text{Ƶ}_{14}(0.1)}{\text{Ƶ}_{13}(0.2)} \quad \text{---------- (18)}$$

Eq.18 shows that 'n' will be less than one (1.0) for $\text{Ƶ}_{13} > \text{Ƶ}_{14}$. This means that with the same amount of resources, the firm would produce lesser number of cars with the automated process even at a lower unit cost of production! Economics would consider Eq.14 more "efficient" than Eq.13 because $\text{Ƶ}_{13} > \text{Ƶ}_{14}$. However, Figure 1 and the calculations above show that the automated process (Eq.14) is less efficient in employment and wealth generation, growth and development in the domicile economy (See References 6 & 7). Moreover, the lower internal participation would make the automated-process cars less competitive in the international market (See Reference 1). The deterioration will make it difficult for the economy to sustain the automated process which then becomes less viable (See Reference 1). This is what I have termed "ECONOMIC PARADOX" (See Reference 1) which is a major cause of economic deterioration in many countries of the world today. It originates from inequitable payments for inputs based on their productivity (See Section 4.1.2) or use of inappropriate technology to achieve greater output rate or better quality. Reference 8 and 9 contain a report on an example of "Economic Paradox" which the European Economic community has

discovered in the manufacture of electronic typewriters and scales in Europe. It should be noted that the capability of the automated process top produce a lot more cars per day (output expansion), would not make Eq.14 more efficient then Eq. 13.

Application of Develonics in economic analysis is contained in Reference 10.

7. CONCLUSION

The conventional view of productivity as output-per-unit input appears to be inaccurate because it ignores output generation efficiency which is a more important component of productivity. This paper has demonstrated that the "Develonic Approach" is a more accurate method of determining productivity in any processes like automation and robotic in construction.

8. REFERENCES

1. Adiele, Chukwumaobi J., "Economics is the Problem", May, 1987. Copy at the Library of NIPSS (National Institute for Policy and Statrategic Studies) Kuru, via Jos, Plateau State, Nigeria where the paper was presented, on April 29, 1988. Copy also at the Nigerian Institute of Social and Economic Research (NISER) Ibadan, Nigeria, Ahumadu Bello University, Zaria, Nigeria and Harvard University, Cambridge, Massachussette, U.S.A.

2. Adiele, Chukwumaobi J., "Develonic Insight Into The Market", April, 1988. Copy at the Library of NIPSS, Kuru, via Jos, Plateau State, Nigeria. Copy also at NISER, Ibadan, Nigeria and Ahumadu Bello University, Zaria, Nigeria and Harvard University, Cambridge, Massachussette, U.S.A.

3. Adiele, Chukwumaobi J., "Construction Management and Methodology", A Lecture given in "SPECIALIST COURSE ON MANAGEMENT OF ENGINEERING PROJECTS" organised by The Nigerian Society of Engineers on September 27-29, 1989 at Lagos, Nigeria.

4. Adiele, Chukwumaobi J., "Restructuring Nigeria Petroleum Industry", PROCEEDING, 11th SPE Annual International Conference (August 1987) Warri, Nigeria.

5. Adiele, Chukwumaobi J., "Develonic Analysis of LNG Impact on Nigeria", PROCEEDINGS, 13th Society of Petoleum Engineers (SPE) Annual Internation Conference at ASCON, Badagry, Nigeria on August 23-25, 1989. "ENGINEERING FOCUS" July-September, 1989 Edition.

6. Adiele, Chukwumaobi J., "Productivity Impacts of Education, Technology and Employment", Paper originally prepared for the National Productivity Centre for presentation at the National Conference on Productivity held at owerri, Nigeria in December, 1987.

7. Adiele, Chukwumaobi J., "Study of Wealth Creation" A paper presented at a special Seminar organised by The Nigerian Institute of social and Economic Research (NISER) at Ibadan, Nigeria on August 2, 1989.

8. Adiele, Chukwumaobi J., "Construction: Growth or Decay Engine in Economy", A paper presented at the 'Workshop on National Construction Policy' organised by Nigerian Society of Engineers at ASCON, Badagry on November 14-18, 1988. "ENGINEERING FOCUS" April-June, 1989 Edition.

9. Adiele, Chukwumaobi J., "Technology and Non-Oil Export", A paper delivered as the distinguished lecturer for August 1989 at the Monthly Technical Seminar of the Federal Ministry of Science & Technology held on August 23, 1989 at Lagos, Nigeria.

10. Adiele, Chukwumaobi J., "Develonic Approach To Analyzing SAP Impacts", Paper presented at the National Conference on "The Impact of the Structural Adjustment Programme (SAP) on Nigerian Agriculture and Rural Life" held on November 27-30, 1989. Organized by Nigerian Institute of Social and Economic Research (NISER) Ibadan, Nigeria and the Friedrich Ebert Foundation of West Germany.