SYSTEM DYNAMICS AND ITS APPLICATIONS
• **Definition**: modelling and simulation tool. Tool, not solution.

• **Purpose**: understand the behaviour of dynamic systems to influence outcomes

• **Method**: graphically build and simulate computer models of their structure.

• **Premise**: structure drives behaviour.

• **Main output**: graphs over time
FOUR BUILDING BLOCKS

• STOCKS AND FLOWS
• CAUSALITY AND FEEDBACKS
• DELAYS
• NON-LINEARITY
“A financial report is presented on two different pages: the balance sheet and the profit and loss statement.

All numbers on the balance sheet are stocks representing accumulations that have evolved over time. The profit and loss statement represents the flows that cause the stocks to change.

There is no comparably important third page, only the page representing stocks and the page representing flows.

That structure of an accounting statement represents a fundamental truth about all systems.”
THE DYNAMICS OF SYSTEMS

Is created by their stocks: the present derives from the past.

Mathematical representation:

- Integration:

\[ \text{STOCK}_{t+dt} = \text{STOCK}_t + dt \left( \text{INFLOW}_t - \text{OUTFLOW}_t \right) \]

- Accumulation (\(dt = 1\)):

\[ \text{STOCK}_{t+1} = \text{STOCK}_t + \text{INFLOW}_t - \text{OUTFLOW}_t \]
CAUSALITY

• Stocks change because flows change.
• Flow variations are the direct or indirect results of changes in stocks.
• Many intermediate variables appear in the causal chain between stocks and flows. All of them must reflect a real occurrence. Some of them are fundamental quantities.
FEEDBACKS: CLOSED CHAINS OF CAUSALITY

Only two types:

• **Reinforcing**: the process is exponential. It explodes. If not checked will lead to catastrophes or extinction (world population, carbon dioxide in atmosphere).

• **Balancing**: the process balances itself. It is goal seeking and leads to equilibrium (reach a sales target).
EXAMPLE: JOHN STERMAN

Renewable Resources
- Harvest
- Generation
- Extraction
- Human activity
- Recycling/decay
- Regeneration
- Ecosystem services

Pollution and Waste
- Generation
- Extraction

Non-Renewable Resources
- Harvest
- Generation
- Extraction

Carrying Capacity
IMPORTANCE OF DELAYS

• Delays cause instability and fluctuations. But if ignored, major system components are discarded.

• Continuous delays
• Discrete delays
• Information delays
NON-LINEARITY

Impact of income per head on fertility
SYSTEMS ARE MODELLED TO GET INSIGHTS - NOT TO MAKE PREDICTIONS (DANA MEADOWS; GEORGE RICHARDSON)

• 10 percent of the modelling generates 90 percent of the insights.

• Simple models for understanding; more complex models to establish confidence.
MODELS THAT MATTER

- Business/economics dynamics
- Supply chain management
- Commodity cycles
- Project management
- Urban dynamics
- Tragedy of the commons
- World dynamics
- Climate change and the environment
- Epidemics
SD ACTIVITY AT AUN (1)

- What is the impact of non-performing loans on Nigerian banks’ survival?
- When and under what conditions will AUN reach financial self-sufficiency?
- Why is Lake Chad shrinking?
- How to make airlines profitable?
SD ACTIVITY AT AUN (2)

• How to protect Nigerian wild birds from extinction through human predation?
• How can Nigeria reduce unemployment?
• Why do people wait so long before getting MTN services?
• How to grow a cooperative?
• How can Nigerian hospitals with limited medical staff cope with surges created by epidemics?
• How to bring almajirai (street children) into formal education?
• Under what conditions can Adamawa state become a large food producer?
SD ACTIVITY AT AUN (4)

• The dynamics of cybercrime (identity management)
• How to control Ebola transmission?
• How to run a bar? (stock management)
DEMONSTRATION:

WILL NIGERIA EVER MAKE IT?
PREAMBLE

“Moses led Israel to the only place in the Middle East that does not have oil”

Hilary Inyang

“Nigeria is worse off than if it never had oil”

Paul Collier
NIGERIA IS HIGHLY POPULATED
Evolution of Nigeria's population 1970-2016

(Source: World Bank)
### 1. 2015 POPULATION (Thousand)

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>MALE</th>
<th>FEMALE</th>
<th>SEX RATIO (females/total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>182,202</td>
<td>92,789</td>
<td>89,413</td>
<td>0.491</td>
</tr>
</tbody>
</table>

### 2. POPULATION HISTORY AND FORECAST (thousand)

<table>
<thead>
<tr>
<th>Population</th>
<th>1950</th>
<th>2015</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>37,860</td>
<td>182,202</td>
<td>262,599</td>
<td>398,508</td>
<td></td>
</tr>
<tr>
<td>World rank</td>
<td>13</td>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

### 3. DISTRIBUTION BY AGE GROUP

<table>
<thead>
<tr>
<th>Percent</th>
<th>Number (thousand)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-14</td>
<td>0-14</td>
</tr>
<tr>
<td>15-59</td>
<td>15-59</td>
</tr>
<tr>
<td>60+</td>
<td>60+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2015</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>35.2</td>
</tr>
<tr>
<td>51.5</td>
<td>58.4</td>
</tr>
<tr>
<td>4.5</td>
<td>6.3</td>
</tr>
<tr>
<td>80,169</td>
<td>140,275</td>
</tr>
<tr>
<td>93,834</td>
<td>232,729</td>
</tr>
<tr>
<td>8,199</td>
<td>25,106</td>
</tr>
<tr>
<td>182,202</td>
<td>398,109</td>
</tr>
</tbody>
</table>

### 4. FERTILITY & LIFE EXPECTANCY

<table>
<thead>
<tr>
<th>Fertility</th>
<th>Life expectancy at birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975/80</td>
<td>1990/95</td>
</tr>
<tr>
<td>2005/10</td>
<td>2010/15</td>
</tr>
<tr>
<td>2015/20</td>
<td>2025/30</td>
</tr>
<tr>
<td>2045/50</td>
<td></td>
</tr>
</tbody>
</table>

| Fertility | 6.76 | 6.37 | 5.91 | 5.74 | 5.41 | 4.74 | 3.59 |
| Life expectancy at birth | 46.1 | 50.2 | 52.3 | 53.7 | 56.7 | 62.3 |

(Source: United Nations)
BUT PEOPLE DO NOT FIND JOBS

(Source: The Guardian newspaper, 26 January 2017)
### Unemployment by Age Group

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Unemployment Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-24</td>
<td>61.7%</td>
</tr>
<tr>
<td>25-34</td>
<td>37.5%</td>
</tr>
<tr>
<td>35-44</td>
<td>15.4%</td>
</tr>
<tr>
<td>45-54</td>
<td>8.8%</td>
</tr>
<tr>
<td>55-64</td>
<td>8.9%</td>
</tr>
<tr>
<td>65-64</td>
<td>9.8%</td>
</tr>
</tbody>
</table>

(Source: NBS, 4th quarter 2016)

### Underemployment by Age Group

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Underemployment Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-24</td>
<td>36.5%</td>
</tr>
<tr>
<td>25-34</td>
<td>22.1%</td>
</tr>
<tr>
<td>35-44</td>
<td>36.5%</td>
</tr>
<tr>
<td>45-54</td>
<td>14.5%</td>
</tr>
<tr>
<td>55-64</td>
<td>12.4%</td>
</tr>
<tr>
<td>65-64</td>
<td>15.1%</td>
</tr>
</tbody>
</table>
NIGERIA HAS PLENTY OIL:

37 billion barrels

AND PLENTY GAS:

192 trillion cubic feet

Total reserve: 71 billion barrels oil equivalent
BUT IT DOES NOT BENEFIT THE ECONOMY
• From **1960 to 1972** (the year before the first oil price boom), Nigeria’s income per head (in **constant** 2005 US$) grew at an average rate of **2.84%** per year.

• But from **1973 to 2013**, it grew at an average rate of only **0.68%** per year. Today it is going down.

• Nigeria’s population grows at an average annual rate of **2.7%**. Today it grows faster than income.

• From **1980 to 2013**, Nigeria has earned more than **one trillion US$** in oil revenue, an average of **US$30 billion** per year.
Electricity is key to development. Although Nigeria’s power generation capacity is reported at 7,000MW in 2017, Nigeria remains a country in the dark (South Africa has about 45,000MW for 53 million people).

Over the period 2004-2011 Nigerians saved 19.7% of the wealth they produced but re-invested only 9.7% of this wealth in Nigeria. This compares to between 21% and 26% for sub-Saharan Africa, the Middle east & North Africa and over 40% for the East Asian tigers.
Over the past 25 years, Nigeria has reinvested on average about 10% of her income into her economy.

(Source: World Bank)
AS A RESULT NIGERIA’S ECONOMY GRAVELY LACKS DIVERSIFICATION

- In 2016, oil and gas provided 95% of foreign exchange earnings and 80% of budget revenues. (Source: Global Edge).

- But the price of oil is subjected to major fluctuations which Nigeria does not control.

Bonny Light crude price 1982-2017
NIGERIA’S SOCIETY IS HIGHLY INEQUAL

Oxfam recently reported that the number of Nigerians living in poverty increased by 62% from 69 million in 2004 to 112 million in 2010.

The monthly salary of a Nigerian senator has been reported to total 29,479,749 naira. At the current CBN exchange rate, this is approximately US$96,650.
Oxfam’s ‘Inequality in Nigeria’

- According to Forbes (2017), the five richest Nigerians [Mr Aliko Dangote (US$12.5 billion), Mr Mike Adenuga (US$10.5 billion), Mr Femi Otedola (US$2.3 billion), Mrs Folorunsho Alakija (US$2.1 billion) and Mr Theophilus Danjuma (US$1.7 billion)] have a combined wealth of US$29.1 billion which could end extreme poverty in the country.

- Remember that from 1980 to 2013 Nigeria earned an average of US$30 billion yearly in oil revenues.
A 2016 CBN report indicates that the total private sector credit exposure of Nigerian commercial banks is \textbf{over 15 trillion naira.}
Over one third of it (5 trillion naira) is on account of only 50 individuals. (100 billion naira or US$333 million each on average)
TWO INDICATORS OF GOOD ECONOMIC MANAGEMENT: THE CURRENCY & THE EXCHANGE RATE
1. THE CURRENCY

“Permit me to issue and control the money of a nation, and I care not who makes its laws!”

Mayer Amschel Rothschild
IN 1973 THE NAIRA WAS INTRODUCED IN 1, 5, 10 & 20 NAIRA NOTES...
... Then in 1991 came the 50 naira notes... Followed in 1999 by the 100 naira notes... A year later came the 200 naira notes... Followed in 2001 by the 500 naira notes... And in 2005 by the 1000 naira notes...

WHEN THIS ONE?
2. THE EXCHANGE RATE

(EVOLUTION OF THE NAIRA COST OF ONE US$)

(Source: Wikipedia)
"In fact just about any long-term model of a real economy should link together the two structures of population and capital to show how they affect each other. The central question of economic development is how to keep the reinforcing loop of capital accumulation from growing more slowly than the reinforcing loop of population growth - so that people are getting richer rather than poorer."

Donella Meadows. Thinking in Systems

"HANDY I "thought experiments" shows that reducing 1) social inequality, 2) population growth, 3) depletion per capita allow society to become sustainable"

Safa Motesharreï, Jorge Rivas, Eugenia Calvay. Human and Nature Dynamics (HANDY)
STEP ONE: IDENTIFY THE MAIN SYSTEM COMPONENTS AND THE MAIN CAUSAL CONNECTIONS WITHIN EACH OF THEM

1. CAPITAL

- PRODUCED CAPITAL
- HYDROCARBONS
- National production / income
- Investment
- Hydrocarbon output
- Return earned
- Net wealth extraction
- External elite wealth

- Depreciation
- Investment
- National production / income
- Produced capital
- Hydrocarbons
- Return earned
- Net wealth extraction
- External elite wealth

Flowchart:
- Production of hydrocarbons leads to national production/income, which influences investment.
- Depreciation affects the flow of wealth.
- Net wealth extraction from external elite wealth.
- Return earned from investment is reinvested, affecting the national economy.
STEP 3: INITIALIZE

- Initial total population: 180 million
- Initial elite population: 20 million
- Initial income per head (total): US$2,500
- Initial income per head (commoners): US$750
- Initial unemployment fraction: 24%
- Initial oil & gas export: 700 million barrels oil equivalent
- Initial net oil revenue: US$30 per barrel
- Commoners’ income fraction: 27%
STEP FOUR: SIMULATE 40 YEARS INTO THE FUTURE

ASSUMPTION: commoners do not save. Their share of the national income is 27%. The elite consumes 60% of its income and reinvest at home 30% of its savings, that is, 12% of its income.

1. If things continue as they are presently, the future of the common man is grim.

2. And the oil price alone does not do much to help even if it goes again above US$100 per barrel.

3. One of the critical parameters is the volume of savings reinvested in the domestic economy. To stabilize unemployment, about 55% of the savings must be reinvested (all other parameters being kept constant). But commoners do not save and it is unlikely that the elite will be willing to reinvest a substantial portion of its income domestically.

4. Socio-economic progress is likely to happen only if commoners gain a larger share of the national income. This will allow them to save and develop the domestic economy. A stronger domestic investment will also attract more of the elite's investments at home.
**BASE SCENARIO: BUSINESS AS USUAL WITH OIL REVENUE AT US$30 A BARREL**

**INCOME PER HEAD**

- **Commoners**: US$4,000 to US$10,000, increasing over time.
- **Elite**: US$40,000 to US$25,000, increasing over time.

**CAPITAL**

- **Domestic capital**: US$0 to US$8M, increasing over time.
- **Oil & gas**: US$0 to US$8M, increasing over time.

**POPULATION**

- **Commoners**: 400 Million to 25 Million, decreasing over time.
- **Elite**: 40 Million to 0 Million, decreasing over time.

**UNEMPLOYMENT (LABOUR SUPPLY - DEMAND)**

- **Labour supply**: 80 Million to 0 Million, decreasing over time.
- **Labour demand**: 80 Million to 0 Million, decreasing over time.

**Key Parameters**

- **Initial oil price**: 0.2 to 0.6
- **Initial income/head commoners**: 500, 750, 1,000
- **Elite consumption fraction**: 0.6
- **Unit hours worked**: 2,300
- **Hydrocarbon export**: 150, 700, 1,000

**Notes**

1. Net oil price
2. Fraction of savings reinvested at home
3. Fraction consumed by commoners
4. Commoners income share
5. Capital effect switch
BUSINESS AS USUAL WITH OIL REVENUE AT US$90 PER BARREL

**INCOME PER HEAD**
- Commoners: US$4,000
- Total: US$40,000
- Elite: US$2,000

**CAPITAL**
- Domestic capital: US$4 million
- Elite wealth: US$6 million
- Oil & gas: US$8 million

**POPULATION**
- Commoners: 600 million
- Elite: 40 million
- Total: 640 million

**UNEMPLOYMENT (LABOUR SUPPLY - DEMAND)**
- Labour supply: 20 million
- Labour demand: 1 million
- Unemployment: 19 million

**Notes:**
1. Net oil price
2. Fraction of savings reinvested at home
3. Fraction consumed by commoners
4. Commoners income share
5. Capital output ratio
6. Unit hours worked
7. Hydrocarbon export
8. Value fraction
9. Fraction consumed by commoners
10. Capital effect switch
FRACTION OF SAVINGS REINVESTED AT HOME GROWS FROM 30 TO 60%

INCOME PER HEAD

- 6,000 US$/head (Commoners)
- 80,000 US$/head (Total)
- 3,000 US$/head (Elite)
- 40,000 US$/head (Domestic capital)
- 0 US$/head (Oil & gas)
- 0 US$/head (Elite wealth)

CAPITAL

- 6 M (Commoners)
- 3 M (Domestic capital)
- 0 (Elite)
- 0 (Oil & gas)
- 0 (Elite wealth)

POPULATION

- 400 Million
- 40 Million
- 200 Million
- 25 Million
- 0 Million

UNEMPLOYMENT (LABOUR SUPPLY - DEMAND)

- 40 Million
- 0.6 Dmnl
- 1 Dmnl
- 1.8 Million
- 1,000

1. Net oil price
2. Fraction of savings reinvested at home
3. Fraction consumed by commoners
4. Commoners income share
5. Capital effect switch
6. Unit hours worked
7. Hydrocarbon export
8. Initial income/head commoners
9. Capital output ratio
PREVIOUS PLUS COMMONERS INCOME SHARE AT 40% AND SAVINGS AT 15%

**INCOME PER HEAD**

- Commoners: 8,000 $/head, 4,000 $/head, 0 $/head
- Elite: 80,000 $/head, 40,000 $/head, 0 $/head

**CAPITAL**

- Domestic capital: US$ million
- Elite wealth: US$ million
- Oil & gas: US$ million

**POPULATION**

- Commoners: 400 Million, 40 Million, 200 Million, 25 Million, 0 Million
- Elite: 40 Million, 0 Million, 6 Million, 12 Million, 18 Million, 24 Million, 30 Million, 36 Million

**UNEMPLOYMENT (LABOUR SUPPLY - DEMAND)**

- Commoners: 8,000 $/head, 4,000 $/head, 0 $/head
- Total: 80,000 $/head, 40,000 $/head, 0 $/head
- Elite: 8,000 $/head, 4,000 $/head, 0 $/head

**Other Key Data**

- Net oil price: 0.2, 0.4, 0.6
- Commoners income share: 0.1, 0.6, 0.1
- Fraction consumed by commoners: 0.85
- Capital effect switch: 1, 2, 1
CONCLUSION

• Nigeria’s real asset is not a commodity (her oil) but a capacity (her people)

• This asset (people) exists in large quantity but the value that it delivers depends upon its quality (value = quantity * quality)

• Low quality turns blessing into curse, high quality turns curse into blessing.
THANK YOU FOR YOUR ATTENTION