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General Concepts about Global Modeling

Some discussions worth taking into account when modeling complex socio-natural systems

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MODELING OF SUSTAINABLE ECONOMIC SYSTEMS

MOSES 2016

May 16-20
Linköping, Sweden

LINKÖPING UNIVERSITY

Global models

- Simulation-oriented mathematical models
  - Express simultaneously several structures and dynamics of a given society under analysis
    - Economy, agriculture, energy, climate, demography, pollution, education, quality of life, etc.
  - A minority also deal with political aspects (e.g. GLOBUS)
  - When the system is the entire planet: “World” Models
- Evident interdisciplinary complexity
  - No strict boundary for the variety of socio natural phenomena meant to be “interconnected”
- Main purpose
  - Evaluate plausible future scenarios (projections)
  - Test feasible actions in order to change the course of events (control actions)
    - Special focus on achieving long term sustainability. Outlook of several decades.
- The discipline climaxed in the mid 70s. Spurred many controversies.
  - No relevant funding since the 80s onwards
  - 90s y 2000s: Interest heavily shifted towards climate change physical modeling
  - The 2010s: Renewed interest (social and economic aspects in the spotlight again)

Global Models. A timeline.

- *Castro R. and Jacovkis P. (2015)*
  Computer-Based Global Models: From Early Experiences to Complex Systems
  Journal of Artificial Societies and Social Simulation 18(1)13

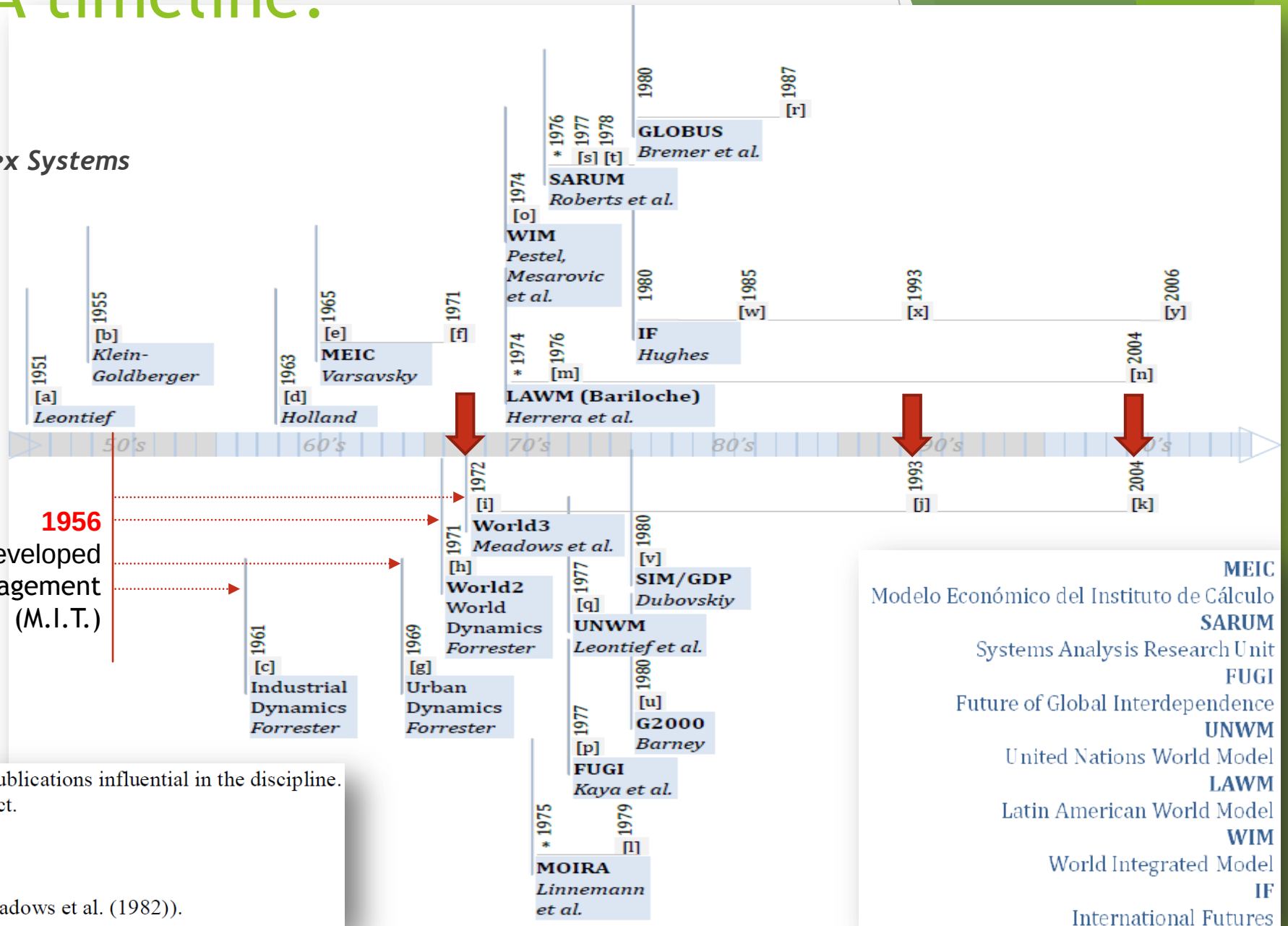
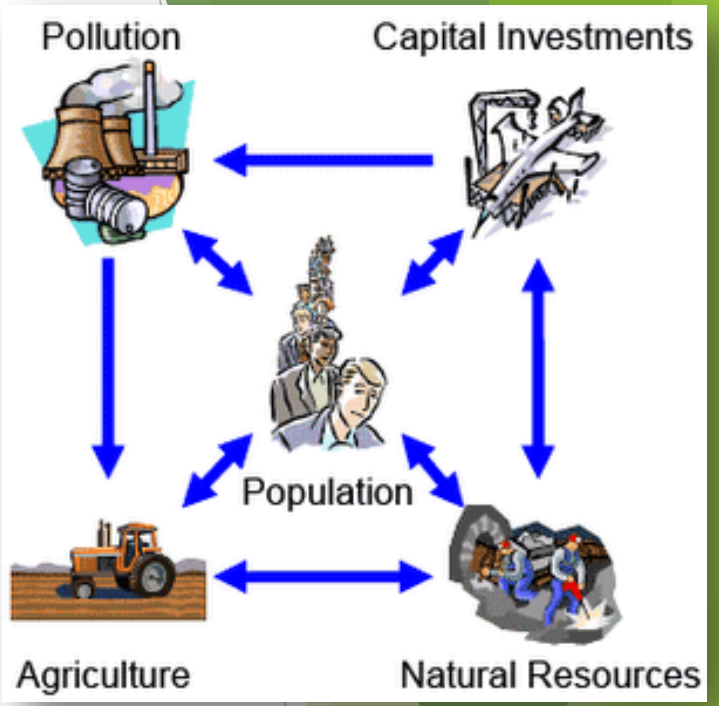


Figure 1 Timeline for a selection of global models and publications influential in the discipline.
Vertical lines | : Approximate earliest activity of the project.
Horizontal lines — : Citations related to the same project.
Acronyms in **bold**: Global Model.
Names in *italic*: Main researcher/author/project director.
Asterisks (*): First report presented at IIASA (source: Meadows et al. (1982)).

The Limits To Growth, 1972 (World3 model)

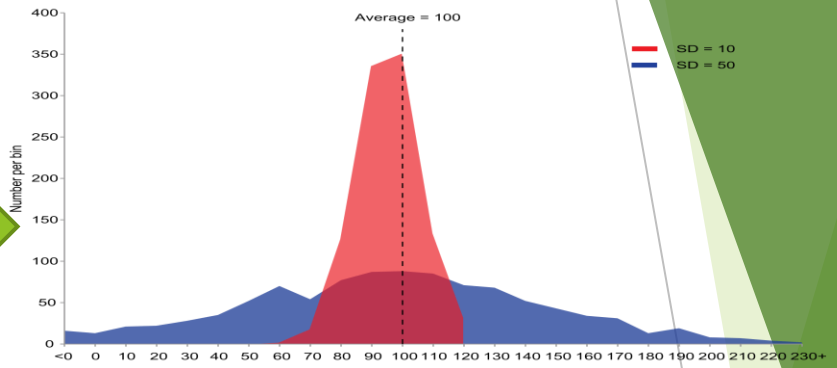


- Based on the System Dynamics modeling approach
- ~10E6 copies, ~30 languages
- 5 sectors. 9 scenarios.
  - Scenario 1: Standard Run ("Business as Usual", famous)
  - Scenarios 2 to 9: Ignored by 99% of the broad public
- Some sensitive aspects
  - Technical
    - System of differential equations
      - Very "sensitive" structure: with ±5% in 5 parameters → drastic change of modes (e.g. Scolnik, H., *A critical review of some global models*, 1979)
      - Daring simplification of complexity: $\dot{X} = F(X) \rightarrow \dot{X} = X_{Normal}.F_1(X_1).\ldots.F_M(X_M)$
      - "Small Signal Approximation" approach. It is risky to project far away from the chosen point of normalization (year 1970)
    - Bivariate input-output functions easily fall out of their domains of validity

World3

- More sensitive aspects
  - Methodological
    - "One single world"
      Operates on **world averages**:
    - Inequality: fair or unfair approach?
    - Methodologically "legal": model a complex reality by incremental approximations
    - Arguable appropriateness:
      - The problems forecasted for the future were already affecting many societies (in the now called "Global South") at the time the model was built.
      - "Solutions" stemming from the simulated trajectories:
        - **Example 1:** Hints that to avoid collapse we should stop growth (is this adequate ?)
        - **Example 2:** Assumption that "there has always been unemployment, it is structural, therefore it is not modeled"
    - Rudolf Kalman: Concept of "System Determinedness" → no "Ohm Law" for social systems. *A system-theoretic critique of dynamic economic models*, 1979.
    - Dennis Meadows: "I don't trust World3 outputs immediately after it starts approaching the population peak" (Personal interview, 2012)

Which "average" world?



World3: Dr. Jekyll

- The Limits to Growth (1972), pg. 94:
  - *Can anything be learned from such a highly aggregated model?*
  - *Can its output be considered meaningful?*
  - *In terms of exact predictions, the output is not meaningful.*
  - *We cannot forecast the precise population of the United States nor the GNP of Brazil nor even the total world food production for the year 2015.*
  - *The data we have to work with are certainly not sufficient for such forecasts, even if it were our purpose to make them.*
  - *On the other hand, it is vitally important to gain some understanding of the causes of growth in human society, the limits to growth, and the behavior of our socio-economic systems when the limits are reached.*

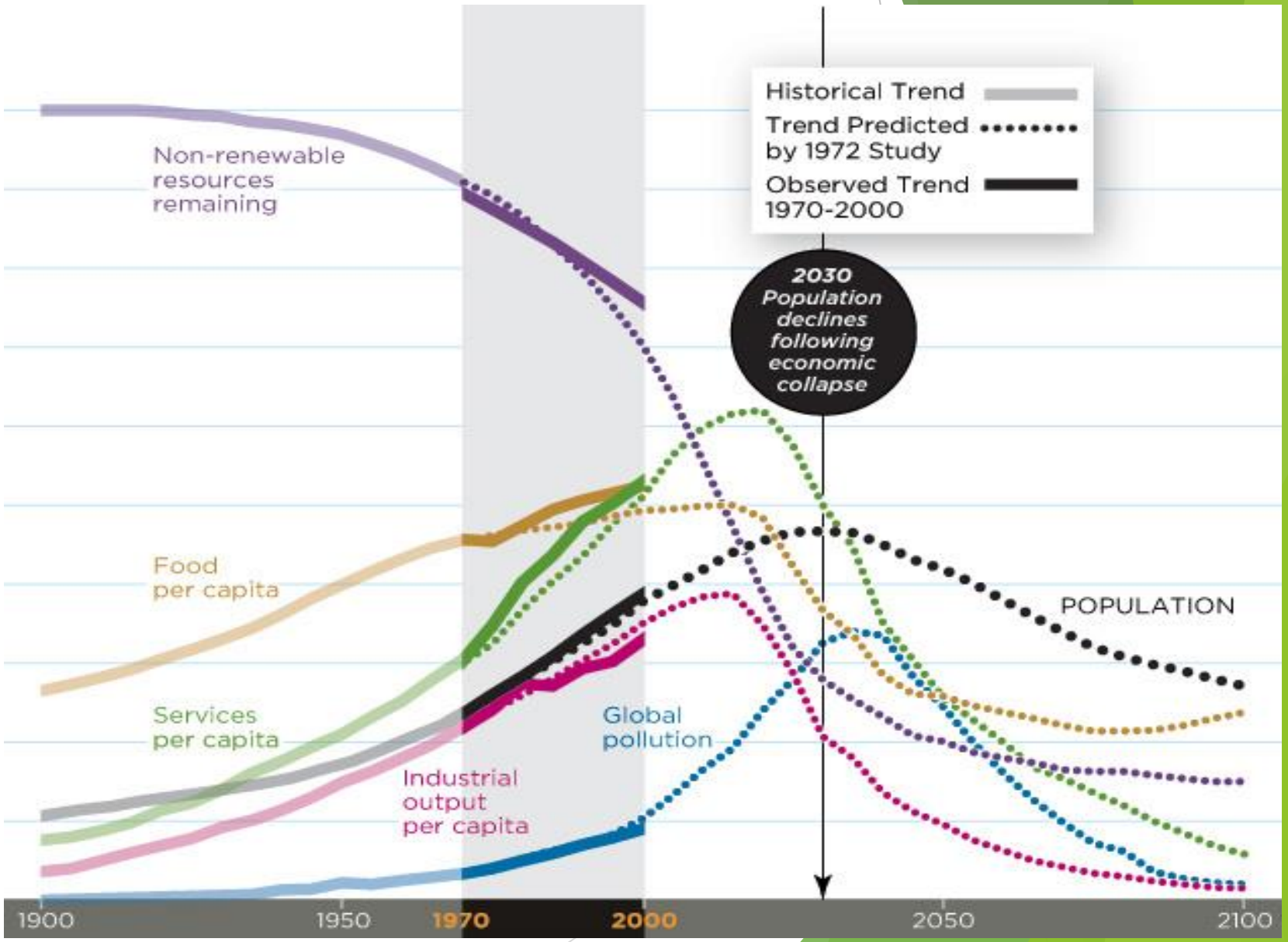
World3: Mr. Hyde (publishing companies)

- The Limits to Growth (1972 edition), back cover:
  - *Will this be the world that your grandchildren will thank you for?*
  - *A world where industrial production has sunk to zero.*
  - *Where population has suffered a catastrophic decline.*
  - *Where the air, sea and land are polluted beyond redemption.*
  - *Where civilization is a distant memory.*
  - *This is **the world that the computer forecasts**.*

World3: Validation

- Question:
  - After having observed 1970-2000, and according to the comparison against World3 (fig. at the right)
  - Is it now more or less likely that the “overshoot and collapse mode” takes place around the middle of the XXI century ?

- Castro, R. (2012). *Arguments on the imminence of Global Collapse are Premature When Based on Simulation Models.*
  GAIA, 21(4):271–273
  - A reaction to Turner, G.M. (2012). *On the Cusp of Global Collapse? Updated Comparison of The Limits to Growth with Historical Data.*
    GAIA, 21(2):116-124



The Latin American World Model (LAWM)

- LAWM 1972-1975 (Bariloche Foundation, Argentina)
- One of many reactions to World3
  - The averaging approach of World3 leaves out possible analyses of world development based on wealth redistribution or similar social equality-oriented approaches.
  - Does not consider explicitly e.g. GINI index, unemployment rate, etc.
- A Latin-American interdisciplinary team
  - Economists, ecologists, mathematicians, sociologists, computer scientists, experts in education, etc.
- Seek to avoid several sensitive aspects in World3
- Make intentions explicit: A **Normative model** (instead of purely **Projective**)
  - *A global model is a structured discourse […] about reality, and as such it necessarily reflects,* ***implicitly or explicitly****, the ideology of actors.*
    - In Loiseau I., Scolnik H.D. et al, *Answering the 6th IIASA Global Modeling Conference questionary*

    in the **great book** "Groping in the dark" by Donella Meadows, J. Richardson, G. Bruckmann. Wiley (1982)

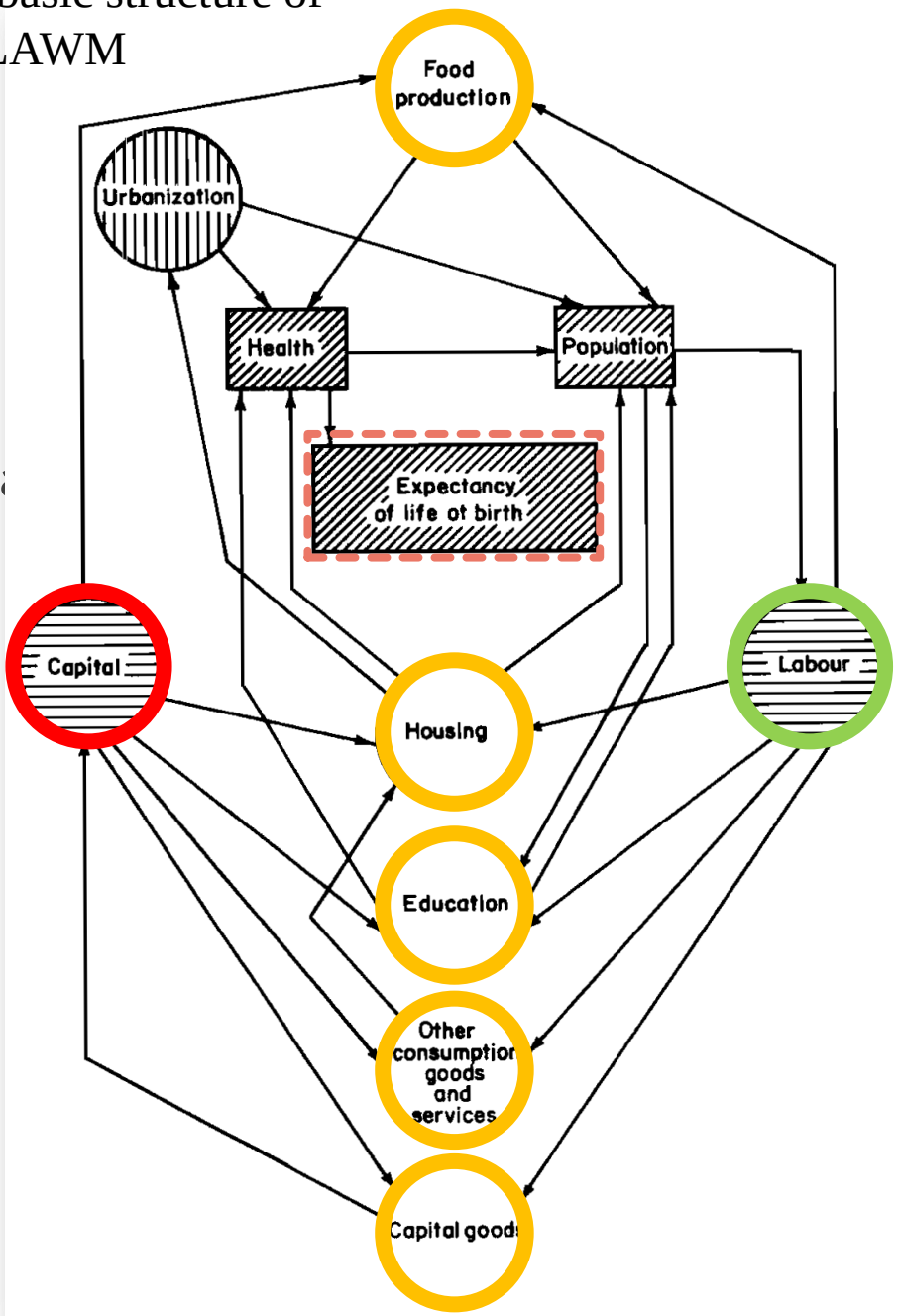
LAWM

- The world:
  - 4 “Blocks” of countries:
    - Developed
    - Latin America & Caribbean
    - Africa
    - Asia & Oceania
  - 5 “Sectors” in the society:
    - Nutrition
    - Housing
    - Education
    - Other Services and Goods
    - Capital Goods
  - Ability to express aid from the developed to underdeveloped blocks
- Key per capita variables:
  - Proteins, Calories, School enrollment, House square meters per family, Life expectancy at birth.
  - GDP is a consequence and not the main metric to be maximized.

LAWM

- Optimization-driven model
  - Allows defining goals and weighed restrictions
    - Goal: To maximize Life Expectancy at Birth (LEB)
    - Adopted as the best integral indicator for human and soci development, sensitive to inequality
  - It assigns resources (Capital and Labor Force) to the productive economic sectors
    - Allows for substitution between capital and labor and reflects improvements in productivity brought about by technological progress
    - Such that LEB is maximized while not violating the provided restrictions
- New custom criteria for “basic needs”
  - Combination of nutrition, housing, education and health
  - Adopted by many organizations, such as the UN, after the report

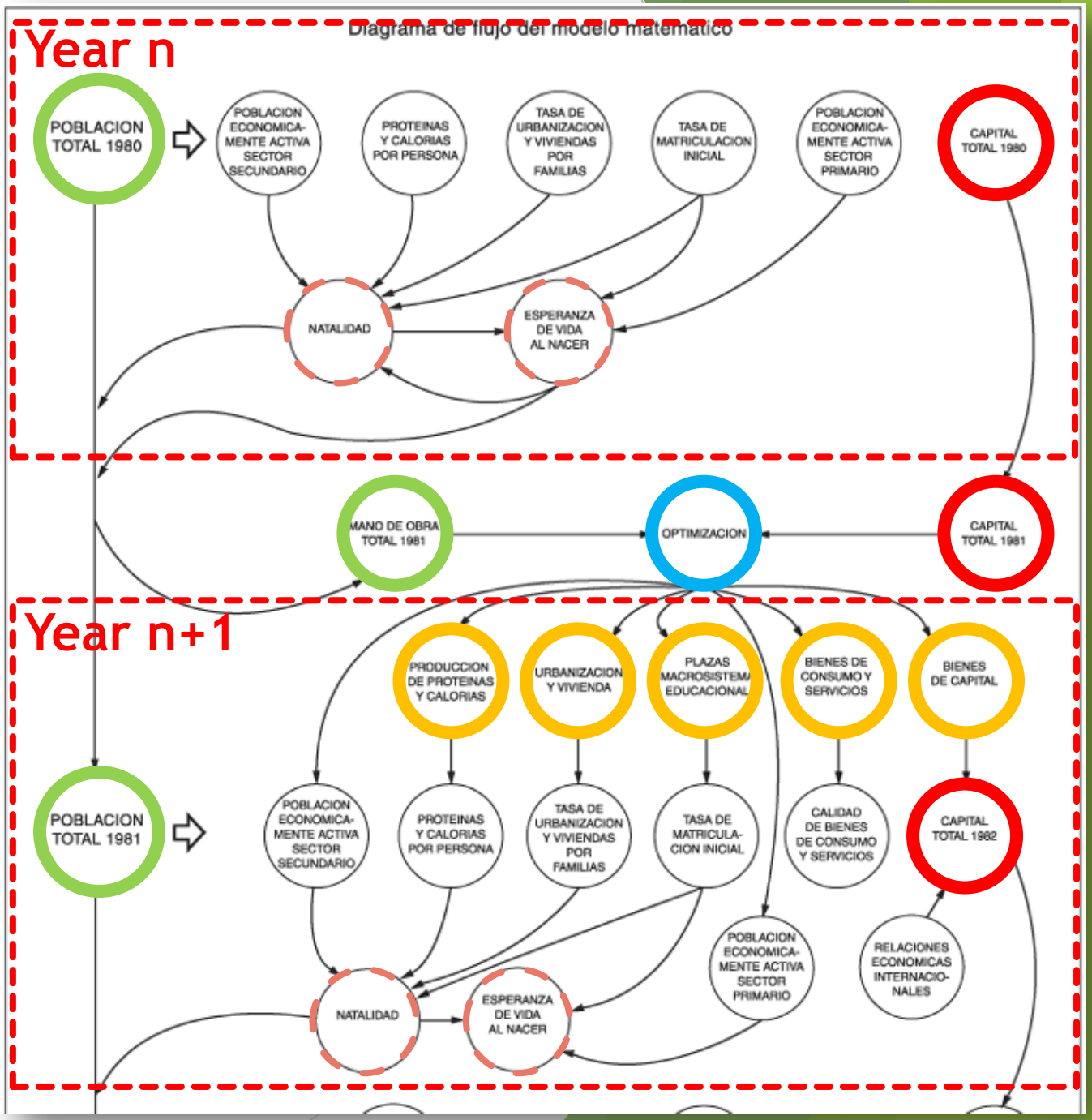
The basic structure of the LAWM



From "Groping in the Dark" Donella Meadows et al (1982)

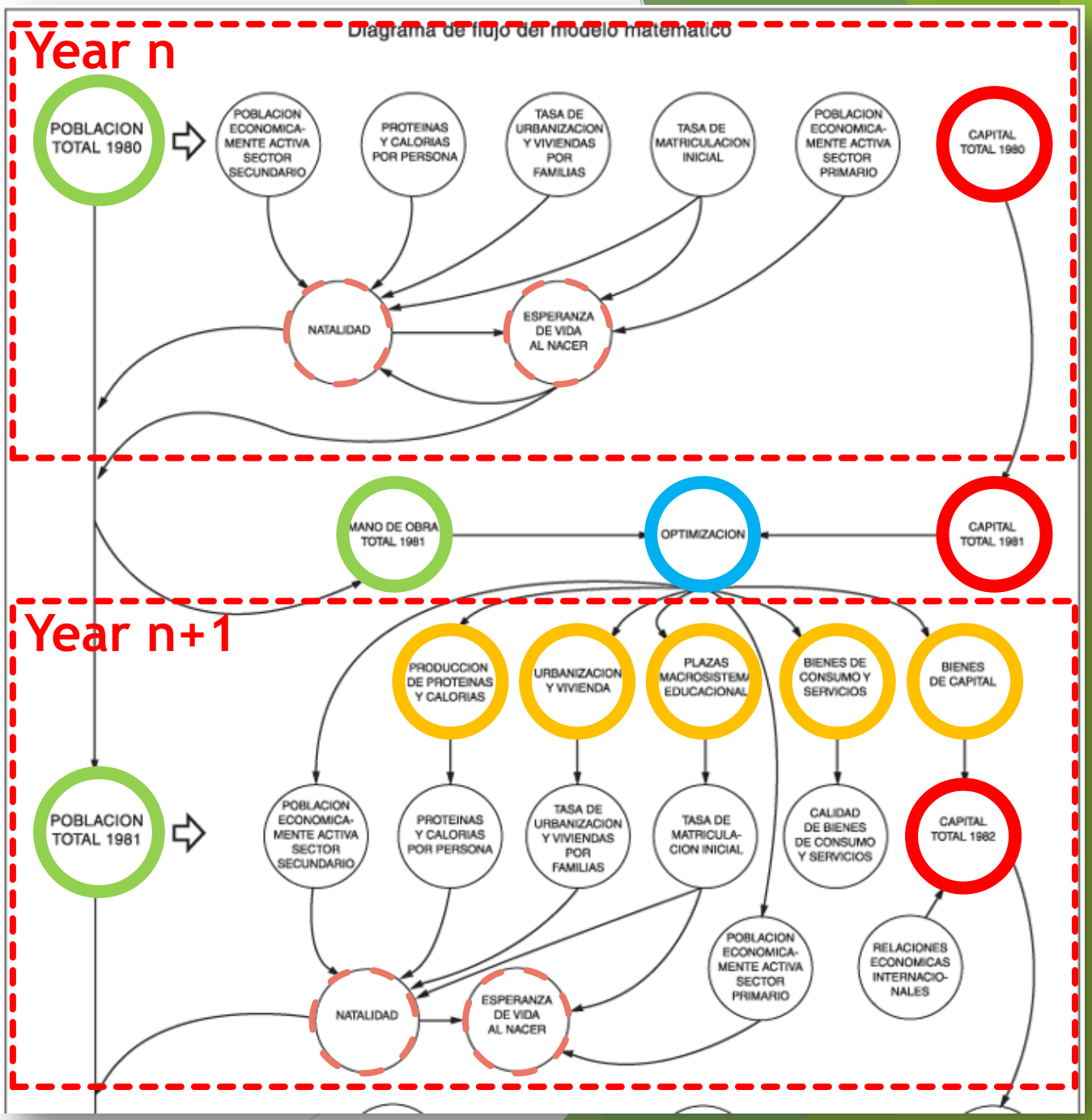
LAWM

- Unique approach: Population size is generated endogenously by a submodel that relates demographic variables to sociopolitical variables
- “The only truly adequate way of controlling population growth is by improving basic living conditions for all”



LAWM

- **Known limitations**
- Minimizes the impact of technological progress
- Myopic optimization
  - Year by year
  - It doesn't deal with attaining the goals "as soon as possible"
- Natural Resources and Pollution are not considered as explicit variables
  - Enter as part of the Production Cost in each sector
- Cross-block solidarity (aid) assumed as "automatic"

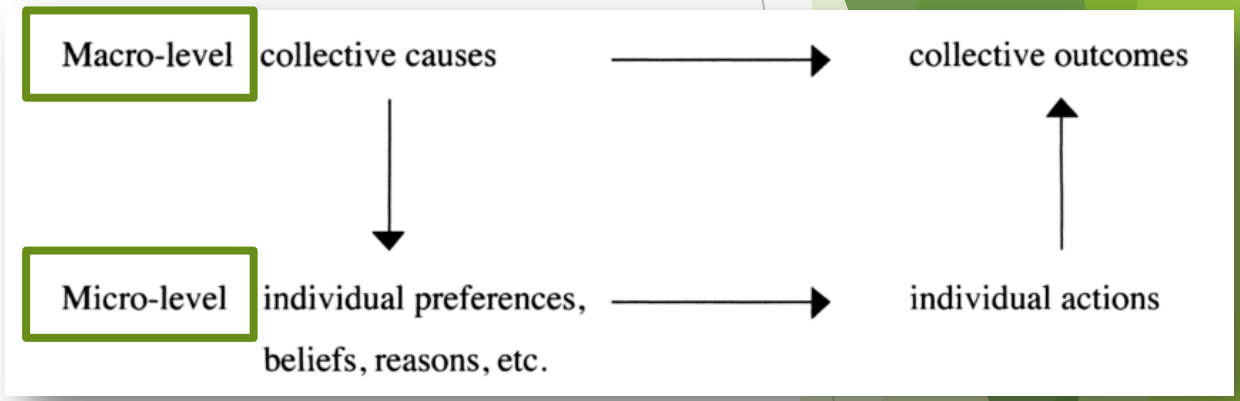


The modular approach in complex social systems

- In the engineer sciences, the evolution and success of computer-based modeling and simulation has witnessed tremendous progresses
  - Based on the concept of modeling complex systems relying on the coupling of simpler submodels
- Worried about cyber-physical systems
- But it is (in comparison) largely underexplored in the socio-natural sciences
- We have reached a situation with many "islands of knowledge" that encode deeply specialized, domain-specific expertise
  - Too often too difficult to interconnect
    - Problem for multi-scale spatio-temporal representation
    - Problem for representing emergent behaviors

Epistemological questions

- Social systems
  - Three main worldviews and research approaches
    - Individualism (composition)
    - Holism (structure)
    - Systemism (Mario Bunge, 2000)
      - Simplest model of a system: Composition-Environment-Structure
      - Allows for emergent behavior
        - A property of the system that is not present in their constitutive parts
      - Boudon-Coleman diagrams

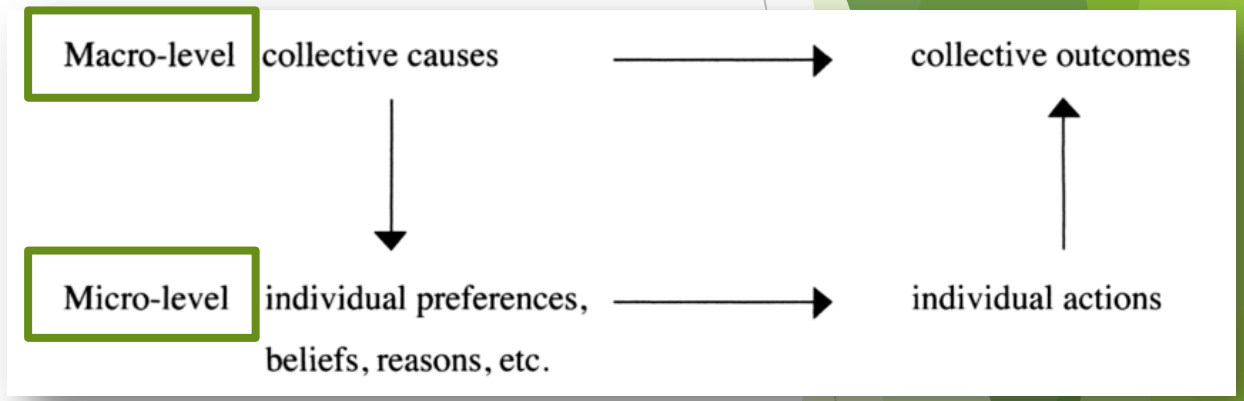


Macrolevel	Economic growth →	Population stagnation
	↓	↑
Microlevel	Old-age security →	Decline in fertility

Macrolevel	Political centralization →	Impoverishment & alienation
	↓	↑
Microlevel	Landlord absenteeism →	Agricultural stagnation & weakening of social ties

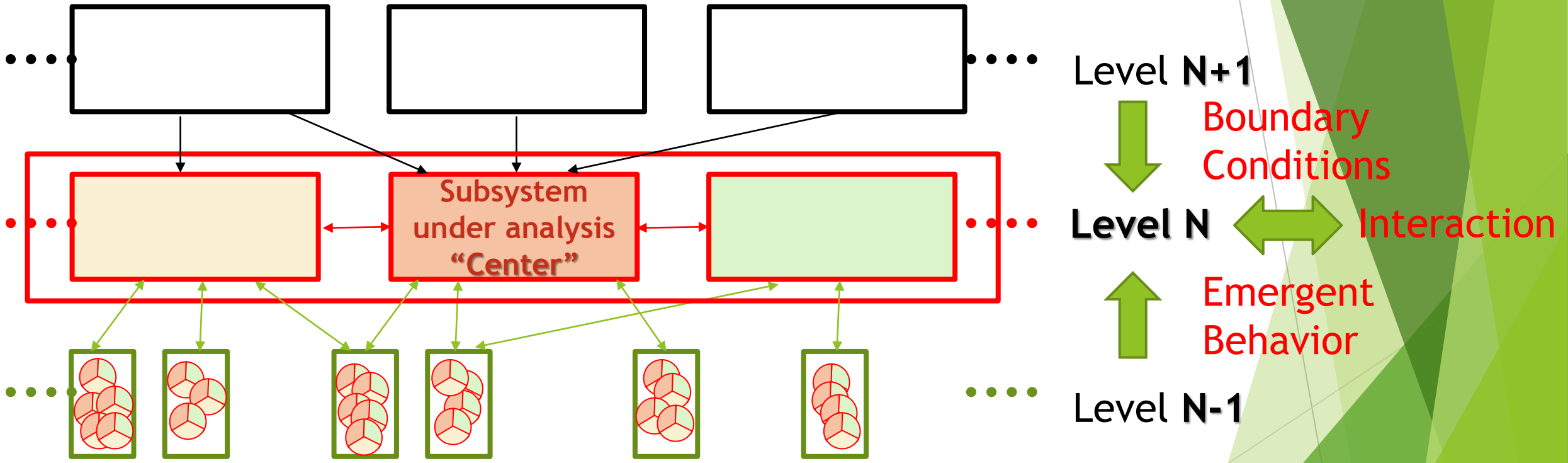
Systemism

- Contribute to the explanation of social change
  - Underlying mechanisms must be revealed
- Macro-micro analysis required
- Top-Down *combined with* Bottom-Up
- N-sectorial
  ("sandwich" problems)
  - Not suitable for analyzing
    "one problem at a time"
- Most well-known global models:
  - Eminently top-down (proposition of alternatives perceived as "central planning")
  - Disaggregation usually at the geographic and population age levels.



Hierarchical Systemism (Castro, 2015)

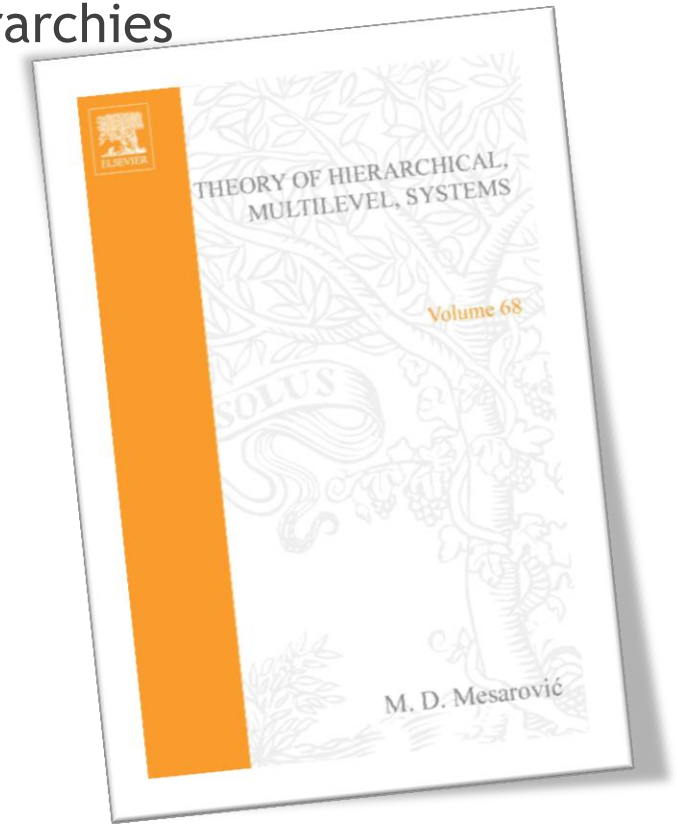
- Methodological proposal for the design of public policies
- Approach: "**Center-Out**". Hierarchical and Composible. Scalable and Reusable. Iterative.



- Mainly "explicative" (pre existing question), as a base for "normative" (pre existing goal).
- Requires to choose appropriately the "Levels", in a reasonable way
  - E.g. based con coherent time-space dynamics

Nothing new under the sun

- M. D. Mesarovic (1970)
- Systems of Systems by means of “strata”
- Control loops “emerge” at different hierarchies



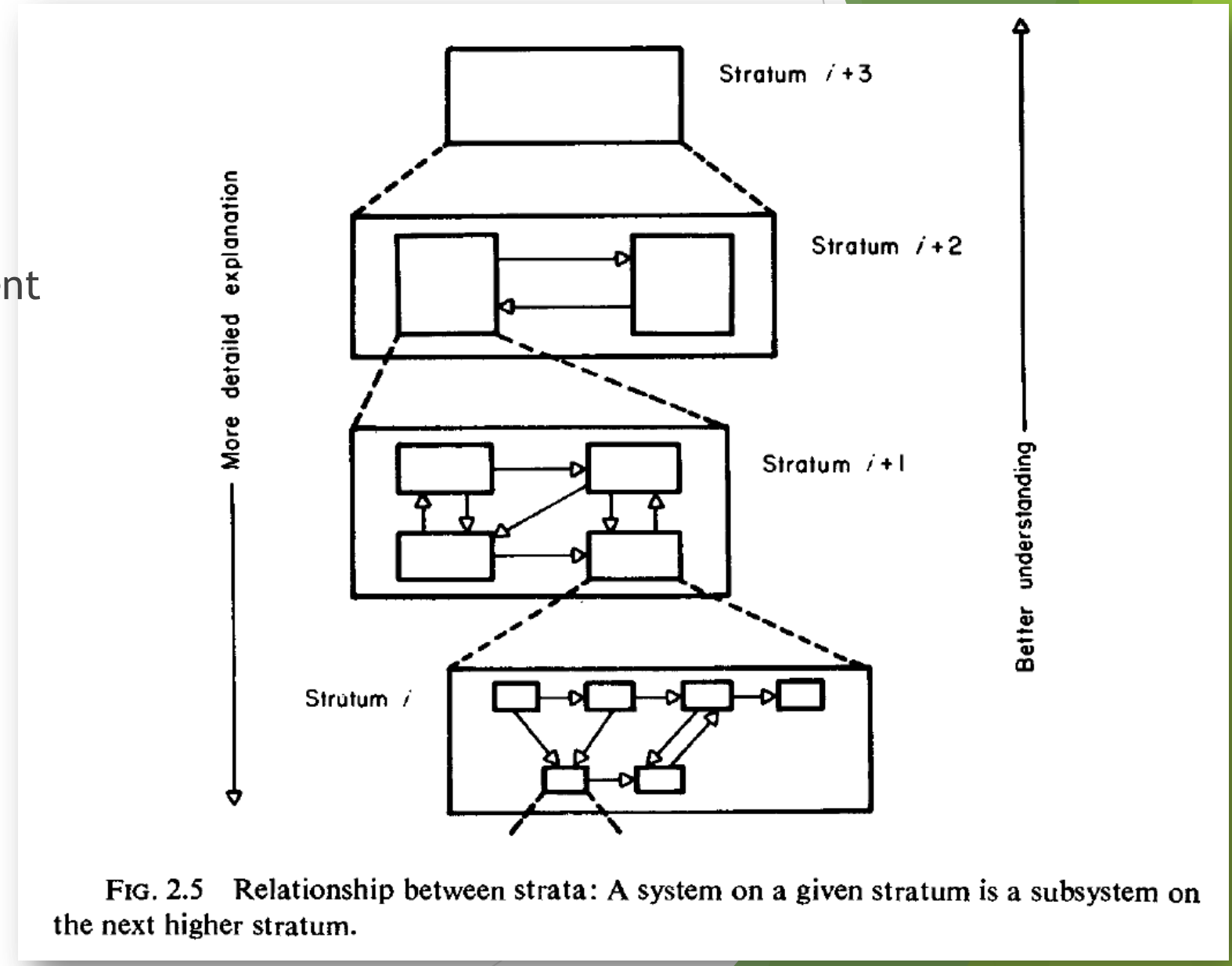


FIG. 2.5 Relationship between strata: A system on a given stratum is a subsystem on the next higher stratum.

Two different ways to look for a key

- “There is more light here”

Someone saw Nasrudin searching for something on the ground.

'What have you lost, Mulla?' he asked. 'My key,' said the Mulla.

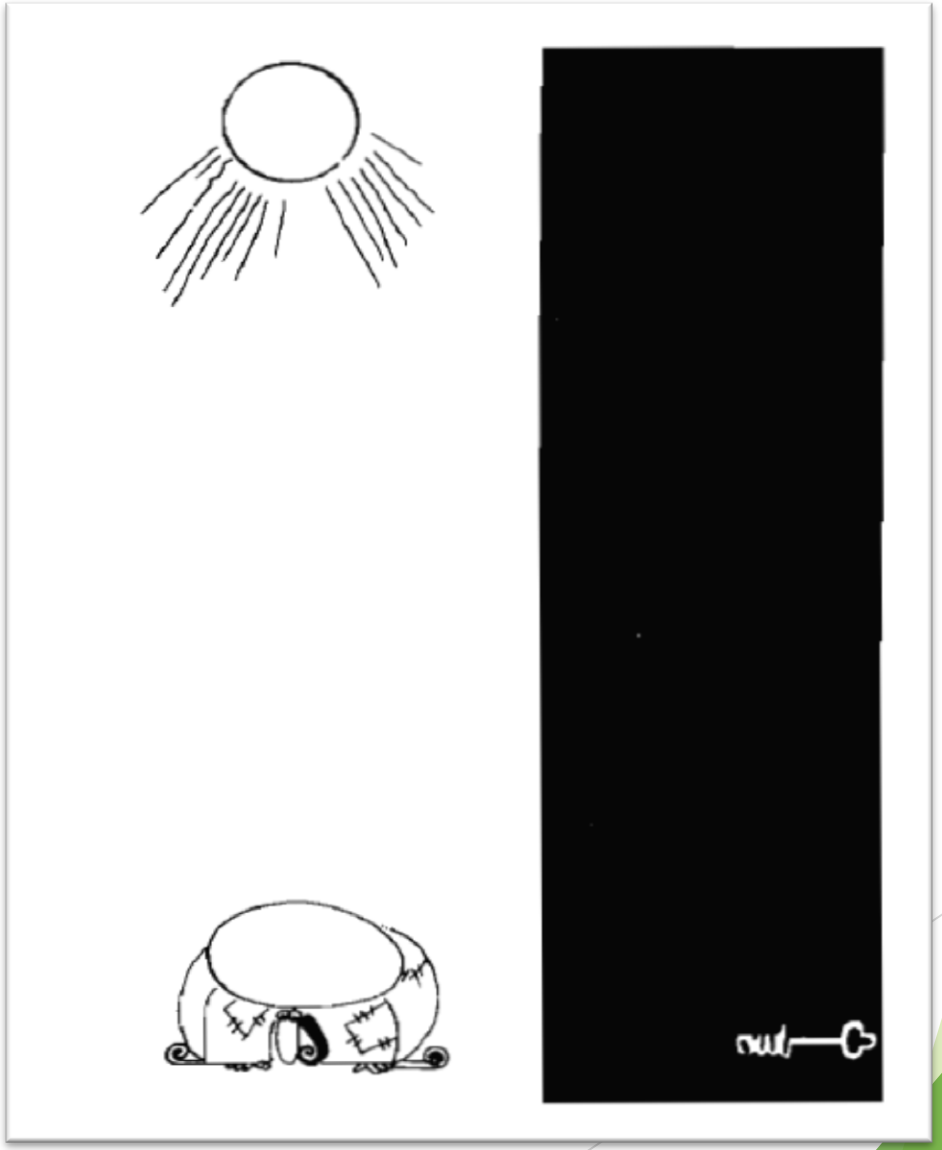
So they both went down on their knees and looked for it.

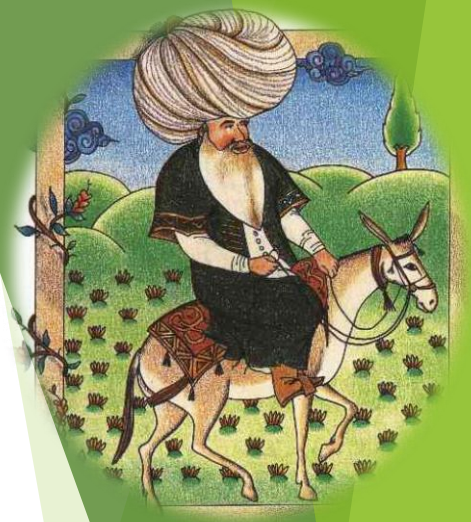
After a time the other man asked: 'Where exactly did you drop it?'

'In my own house.'

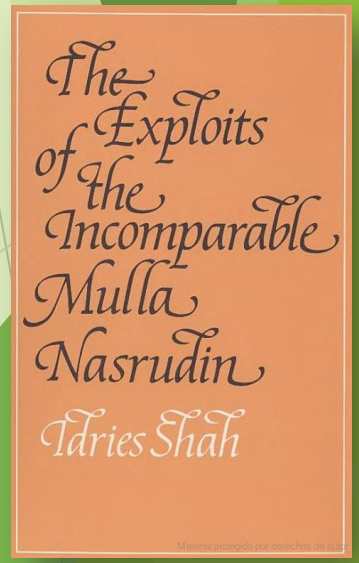
'Then why are you looking here?'

'There is more light here than inside my own house.'





From ***The Exploits of the Incomparable Mulla Nasrudin*** by Idries Shah (1983)



Two different ways to look for a key

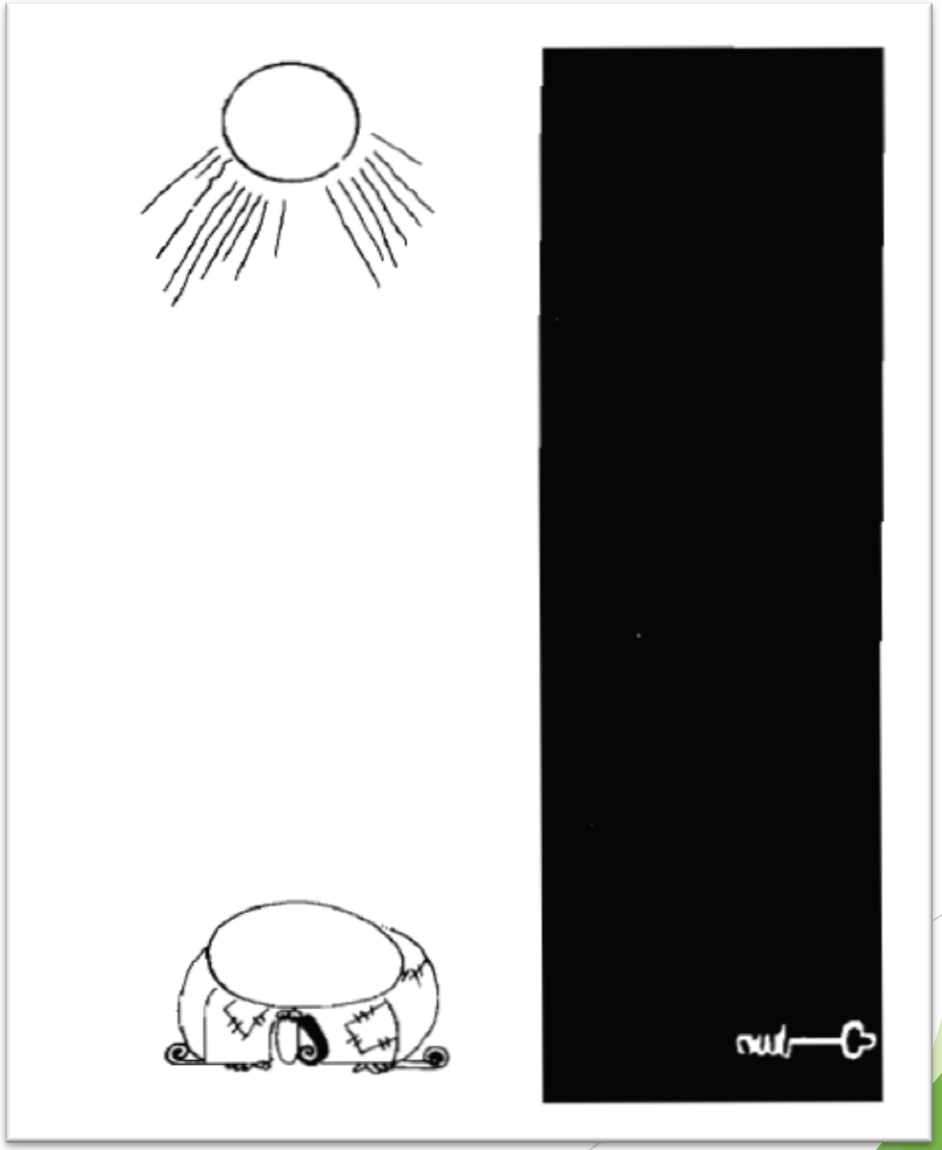
- From a global modeler to another

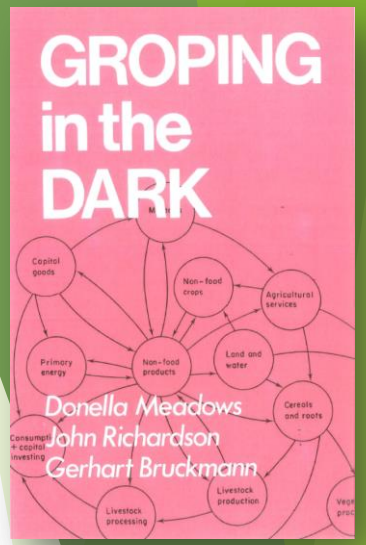
"The key **both you and I** are trying to find is the solution to the critical problems mankind will face in the coming decades. Each of us is searching with sincerity and devotion.

What is **profoundly different**, however, is our **basic strategy**.

You stand in the light, trying to **move the light post closer to the place where the key might be**.

I, on the other hand,
am groping in the dark"





From ***Groping in the Dark*** The first decade of global modelling *(1982)*

- The Forrester/Meadows models
- The Mesarovic/Pestel model
- The Bariloche model
- The MOIRA model
- The SARU model
- The FUGI model
- The United Nations global model

Conclusions

- We deal with complex interdefined socio-natural systems at multiple levels of abstraction
  - Different approaches required
    - Complementary
    - Simultaneous
  - How to integrate them in a robust, scalable, non-ambiguous way ?
- **No silver bullet. Work needed!**
- **We need better modeling formalisms**
  - **Generic enough**
    - But not too much so that to make them ambiguous
  - **Specific enough**
    - But not too much so that to get trapped within specific programming languages
  - **Rigorously separable from the underlying simulation technology**
  - **Readily connectable and runnable**
    - By means of well specified simulation algorithms

Conclusions

- We must be able to study complex systems of systems
  - We need tools that help us in determining the "consistency" of the interconnection of subsystems
    - In terms of the interconnection
      - **Parameters** at one level are
        - Emergent properties determined by dynamic, faster variables at "lower levels"
        - Boundary conditions determined by dynamic, slower variables at "upper levels"
    - In terms of time and scale

Questions

?