International Institute for Applied Systems Analysis: short overview

Elena Rovenskaya
IIASA Advanced Systems Analysis Program
What is IIASA?

• IIASA is an **international** scientific institute that conducts **policy-oriented research** into problems that are too large or too complex to be solved by a single country: independent, non-governmental organization

• Topics: climate change, energy security, population aging, economic growth, etc: **interdisciplinary character** => integrated assessment

• Important issues: **stakeholder involvement**, bridge **science-policy** divide

• Nearly 200 natural and social scientists, mathematicians, and engineers from over 35 countries research at IIASA
IIASA’s history

- After the Second World War: a growing number of complex scientific and technological problems could no longer be examined on a purely national basis: a global approach through international cooperation was required.

- The idea of an “East-West Institute” began to take shape in the 1960s through discussions between the USA and the USSR.

- Through the Ambassador to the USSR, Austria suggested the 18th century Habsburg palace Schloss Laxenburg as a site.

- On 4 October 1972, the Institute was officially constituted in London under the auspices of the Royal Society as the International Institute for Applied Systems Analysis (IIASA).

- 12 National Member Organizations (NMOs) from Canada, Czechoslovakia, Bulgaria, East Germany, France, Italy, Japan, Poland, the Soviet Union, the United Kingdom, the United States, and West Germany signed the Charter.

- Now: North-South orientation in addition to East-West, large networks.
Current IIASA’s structure

Contributions of member-countries (currently 20, incl. USA, Russia, Germany, Austria, China, Finland, Sweden, Norway, Japan, …)

External funding (EU, grants from national foundations, contracts etc)

IIASA

Scientific impact: papers, books, conferences

Policy impact: reports for policy-makers, meetings, targeted research
Research at IIASA

8 research programs:

- **Advanced Systems Analysis (ASA)**
- Ecosystems Services and Management (ESM)
- Energy (ENE)
- Evolution and Ecology (EEP)
- Mitigation of Air Pollution (MAG)
- Risk, Policy, and Vulnerability (RPV)
- Transitions to New Technologies (TNT)
- World Population (POP)

ASA’s goal: to **advance systems analysis**, which uses mathematical models and analytical techniques to investigate **complex systems** with a focus on an **integrated, interdisciplinary approach**.
ASA: Some figures and facts

- 15 research scholars/senior research scholars and 3 research assistants
- **Network**: Most of the staff have their main affiliations elsewhere (Russia, Ukraine, Finland, Japan, Austria, USA)
- Disciplinary backgrounds: applied mathematics, ecology, social sciences, economics
- ASA’s research strategy includes: (i) development of **new systems-analytic methods** rooted in IIASA’s applied research, (ii) development of feedback between systems methods and applied research on global change, and (iii) **demonstration** to a broad scientific audience of **new knowledge** obtained through the use of the new methods
### Main research themes

<table>
<thead>
<tr>
<th>Dynamic systems</th>
<th>Assessment of Dynamical Systems</th>
<th>Systemic Risks and Robust Solutions</th>
<th>Integrated Modeling and Decision Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management of heterogeneous dynamical systems</td>
<td>Systemic risk and network dynamics (in collaboration with EEP)</td>
<td>Model integration (COMPLEX)</td>
<td></td>
</tr>
<tr>
<td>Networks</td>
<td>Network analysis in ecology</td>
<td></td>
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<tr>
<td></td>
<td>Systemic risk, security and robust solutions</td>
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<tr>
<td>Optimization</td>
<td>Global economic growth and optimization (in collaboration with POP)</td>
<td>Multi-criteria analysis</td>
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<td>Assessment of resource productivity</td>
<td>Operating energy efficient buildings (EnRiMa)</td>
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<td></td>
<td></td>
<td>Food, water and energy security management</td>
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<tr>
<td>Game theory</td>
<td>Sustainable forest management (in collaboration with ESM &amp; EEP)</td>
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<tr>
<td>Agent-based modeling</td>
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<td>Artificial world for forecasting (Dream Valley)</td>
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<tr>
<td>Qualitative analysis</td>
<td>Drivers of extreme events</td>
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</table>
Thanks for your attention and welcome to IIASA!
Approaches to science-based support of decision-making in regional economic development

Elena Rovenskaya
IIASA Advanced Systems Analysis Program
Two approaches

• **Systems dynamics**
  ..an approach relying on causal loop diagrams and accumulating flows into stocks

• **Agent-based modeling**
  ..an approach relying on simple behavioral rules of multiple interacting agents which emerge into a complex systems behavior

Both approaches have been proven to be effective tools for the science-based support of the decision-making in various fields including economy, social sphere, environment etc.

SCOPUS database, 2012:
SD: about 27,000 papers
ABM: about 20,000 papers
Systems dynamics

A flow contributes to a stocks:

Where does a flow come from? Via feedback loops from another stock (as its share!) and from outside the system (external scenarios)
An agent-based model should consist of
• numerous agents specified at various scales
• agents’ decision-making rules
• learning rules or adaptive processes
• interaction topology
• non-agent environment
## Comparison of the two approaches

<table>
<thead>
<tr>
<th></th>
<th>Power</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Systems dynamics</strong></td>
<td>Tractable feedback loops</td>
<td>Aggregated representation, simple decision rules</td>
</tr>
<tr>
<td>(SD)</td>
<td>Requires little computer resources, easy to program</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Agent-based</strong></td>
<td>More realistic representation of actors and their interactions</td>
<td>Many parameters, difficult to calibrate</td>
</tr>
<tr>
<td><strong>modeling</strong></td>
<td>Decentralized decisions</td>
<td>Requires more computer resources, difficult to program</td>
</tr>
<tr>
<td>(ABM)</td>
<td></td>
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</tbody>
</table>
Model I: Systems dynamics of regional economic development
### Model I: Systems dynamics of regional economic development

**Main actors in the model:**
Municipalities, Companies, Distributors, Public sector, Employed, Unemployed, Retired

<table>
<thead>
<tr>
<th>Main stocks:</th>
<th>Main flows:</th>
<th>Main external variables:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Actors’ cash stocks</td>
<td>• Companies’ production</td>
<td>• Export</td>
</tr>
<tr>
<td>• Companies’ accumulated debts</td>
<td>• Local demand</td>
<td>• Import</td>
</tr>
<tr>
<td>• Companies’ accumulated profit</td>
<td>• Total consumption</td>
<td>• State subsidies to municipalities and employed</td>
</tr>
<tr>
<td></td>
<td>• Taxes paid by actors to the local and state governments</td>
<td>• Pensions, unemployment benefits</td>
</tr>
<tr>
<td></td>
<td>• Salaries paid by companies, distributors and social services</td>
<td>• State salaries</td>
</tr>
</tbody>
</table>
Model I: Systems dynamics of regional economic development
Model I: Systems dynamics of regional economic development

Parameters that need to be defined (about 20):

Companies:
- Profit share allocated for investment
- Cost structure: shares of labor cost, materials and energy cost
- State tax rate

Distributors:
- Profit margin
- Share of labor cost
- State tax rate

Municipalities + Public sector:
- Share of labor cost
- Tax rates for other actors

Employed:
- Consumption share
- State tax rate

Unemployed:
- Consumption share

Retired:
- Consumption share
- State tax rate
Model I: Systems dynamics of regional economic development

General concept of the analysis:

Two modes of operation: constant and non-constant exogenous inputs

Property of SD models: with constant outputs the dynamics stabilizes very quickly => stationary process independent on the initial state

Stationary process: dynamics with constant over time variables dependent only on the external inputs

Allows for simpler and more comprehensive analysis of the impact of changes in some external scenario onto the main state variables
Model I: Systems dynamics of regional economic development

Task 1: sensitivity analysis of the main state variables

<table>
<thead>
<tr>
<th>Input (parameter) uncertainty</th>
<th>Uncertainty in main variables (total salaries, total consumption, total production, total taxes, unemployment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input uncertainty: 20%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Max</th>
<th>Uncertainty</th>
<th>Uncertainty per 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipalities income</td>
<td>1726</td>
<td>7858</td>
<td>355%</td>
<td>18%</td>
</tr>
<tr>
<td>Total salaries</td>
<td>8378</td>
<td>49479</td>
<td>589%</td>
<td>25%</td>
</tr>
<tr>
<td>Total consumption</td>
<td>7247</td>
<td>32615</td>
<td>350%</td>
<td>18%</td>
</tr>
<tr>
<td>Total production</td>
<td>6027</td>
<td>23711</td>
<td>293%</td>
<td>15%</td>
</tr>
<tr>
<td>Total taxes</td>
<td>1590</td>
<td>7722</td>
<td>385%</td>
<td>19%</td>
</tr>
<tr>
<td>Savings of employed</td>
<td>2888</td>
<td>19901</td>
<td>589%</td>
<td>29%</td>
</tr>
<tr>
<td>Savings of unemployed</td>
<td>16</td>
<td>49</td>
<td>200%</td>
<td>29%</td>
</tr>
<tr>
<td>Savings of retired</td>
<td>67</td>
<td>210</td>
<td>213%</td>
<td>11%</td>
</tr>
</tbody>
</table>
### Model I: Systems dynamics of regional economic development

**Task 2: sensitivity results of the elasticity**

**Elasticity of Y with respect to X:** the percentage change of Y corresponding to 1% change of X

<table>
<thead>
<tr>
<th></th>
<th>Export</th>
<th>Import</th>
<th>State subsidies to municipalities</th>
<th>State subsidies to employed</th>
<th>Pensions</th>
<th>Unemployment benefits</th>
<th>State salaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipalities income</td>
<td>137…173%</td>
<td>-156…-124%</td>
<td>8…15%</td>
<td>8…10%</td>
<td>43…46%</td>
<td>10…10%</td>
<td>9…10%</td>
</tr>
<tr>
<td>Total salaries</td>
<td>152…182%</td>
<td>-164…-137%</td>
<td>8…9%</td>
<td>10…10%</td>
<td>43…45%</td>
<td>10…10%</td>
<td>10…12%</td>
</tr>
<tr>
<td>Total demand</td>
<td>156…422%</td>
<td>-571…-134%</td>
<td>8…26%</td>
<td>9…30%</td>
<td>41…133%</td>
<td>9…31%</td>
<td>9…29%</td>
</tr>
<tr>
<td>Total production</td>
<td>162…203%</td>
<td>-183…-146%</td>
<td>8…9%</td>
<td>10…10%</td>
<td>43…45%</td>
<td>10…10%</td>
<td>9…10%</td>
</tr>
<tr>
<td>Total taxes</td>
<td>146…176%</td>
<td>-159…-132%</td>
<td>8…9%</td>
<td>8…10%</td>
<td>41…133%</td>
<td>10…10%</td>
<td>10…12%</td>
</tr>
<tr>
<td>Savings of employed</td>
<td>150…180%</td>
<td>-162…-135%</td>
<td>8…9%</td>
<td>10…12%</td>
<td>42…45%</td>
<td>10…10%</td>
<td>10…11%</td>
</tr>
<tr>
<td>Savings of unemployed</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>100%</td>
<td>-</td>
</tr>
<tr>
<td>Savings of retired</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Model I: Systems dynamics of regional economic development

Task 3: re-adjustment of policies in case of shock scenarios

- Change in any external scenarios (as compared to BAU case)
- “Targeted” change of some system’s parameters (as compares to BAU case)
  - Taxes to be paid to municipalities
  - Salaries in public sector
- State variables remain the same (as compared to BAU case)
Model I: Systems dynamics of regional economic development

Task 3: re-adjustment of domestic policies in case of shock scenarios

Drop in export by 30%

<table>
<thead>
<tr>
<th></th>
<th>BAU value</th>
<th>Adjusted value</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxes from companies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxes from distributors</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Taxes from employed</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Taxes from unemployed and retired</td>
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<td></td>
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<tr>
<td>Salaries in public sector</td>
<td></td>
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</tbody>
</table>
Model II: Agent-based modeling of regional economic development
Model II: Agent-based modeling of regional economic development

Main agents in the model:
- Municipalities
- Companies (11 sectors: industry, agriculture, construction, trade, hotels and restaurants, information and communication, administration, public sector, education, health and social services, other)
- Individuals (can be employed, unemployed, students, children, retired; can have high education or not, have different social mood)
Model II: Agent-based modeling of regional economic development

**Companies**
- Produce goods based on the estimates of the total demand (intermediate, final domestic and export)
- Pay salaries and taxes

**Municipalities**
- Collect taxes
- Pay subsidies

**Individuals**
- Get born, grow up, become adults and pass away
- Total income consisting of salaries and social transfers forms the final domestic demand

**Immigration**
- (depending on social mood)

**Emigration**
- (depending on social mood)

**Social transfers**
- Subsidies into public health and education

**Taxes**
- Buy goods

**Loans**
- Subsidies, Loans

**Subsidies**
- Buy goods

**Labor**
- Subsidies into public health and education

**Export**
- Import
Model II: Agent-based modeling of regional economic development

State chart of municipalities
Model II: Agent-based modeling of regional economic development

State chart of a company
Model II: Agent-based modeling of regional economic development

State chart of an individual
Model II: Agent-based modeling of regional economic development

Main parameters that need to be defined (more than 120 in total)

- Birth and mortality rates, immigration rate
- Shares of intermediate consumption (input-output tables)
- Tax rates
- Individuals’ consumption rates depending on their age and job status
- Cost structure of companies, incl. labor cost, cost of materials and energy, profit rate etc.
- Ratio of employees with high education needed in each sector
- Interest rates and loan’s time
- Impact of social mood on emigration
- Impact of social transfers on health and number of people going to universities
- …
Model II: Agent-based modeling of regional economic development

Input scenarios

- Export
- Social transfers to households
- State subsidies to municipalities
- State subsidies to companies
- Social mood
Model II: Agent-based modeling of regional economic development

Demonstration in AnyLogic