Agent Based Macro Modelling - Model design and validation

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Model Life-cycle

- Model design
  - Research Question and stylised facts
  - Thinking agents
  - Sequence of events
- Model Calibration
- Model Simulation
- Result analysis
  - Overall dynamics
  - Validation
  - Sensitivity and Robustness analysis

Outline

The crucial role of Stylized Facts

Roughly, the logic of macroeconomic AB modeling consists of two pillars.

i First, empirical laws at a macroeconomic level should be expressed in terms of statistical distributions, such as the distribution of people according to their income or wealth, or the distribution of firms according to their size or growth rate [Steindl, 1965].

ii Second, suitable modeling strategies should be adopted, that is explanatory methodologies capable to combine a proper analysis of the behavioral characteristics of individual agents and the aggregate properties of social and economic structures [Sunder, 2006].

Hence the role of stylized facts in thinking an ABM is twofold:

- Micro stylized facts provide a **guide to define the characteristics** of the environment in which economic actors operate and their behavioral rules;
- Then, an ABM model aims to explain how the disperse interaction of micro agents *generate* macro stylized facts as emergent properties of the system (**validation**).

Some examples of stylized facts I

Some "Meso" stylized facts on relevant distributions:

- Since Gibrat (1931) the size **distribution** of firms has proven to be **right skewed, with upper-tails made of few large firms**, for several different countries and historical periods [De Wit, 2005]. These patterns vary significantly across industries Bottazzi and Secchi [2003a,b]. In some cases firms dimension is a Log-Normal, in other a Power law (see Grilli's next lectures)
- The **distribution** of firms' growth rates appears to be approximated by a Laplace (double-exponential) distribution Amaral et al. [1997], Bottazzi et al. [2002], that is a **fat-tailed, tent-shaped** distribution.
- Earnings, income and wealth are well known to be **highly concentrated over households**, regardless of the measure of concentration. Power-law distribution of the right tail.
- Firms' debt and bankruptcy rates are Power Law distributed.
- Bank credit and credit degree distribution have fat tails.

Some examples of stylized facts II

Macro SF (relative volatility, auto and cross-correlations of macro variables)

1. Investment is considerably more **volatile** than GDP. Consumption is less volatile than output.
2. Investment, consumption and changes in inventories tend to be **pro-cyclical and coincident** variables. Inflation **pro-cyclical and lagging**, mark-ups **countercyclical**. The inventories/sales ratio is counter-cylical.
3. Aggregate employment and unemployment rates tend to be lagging variables. The former is pro-cyclical, whereas the latter is anti-cyclical.
4. Bank leverage is pro-cyclical.
5. Pro-cyclical firms' debt and bankruptcy rates.

Some examples of stylized facts III

Micro SF

1. Investment is **lumpy** (not smoothed, instead concentrated in certain periods). Investment is influenced by firms' financial structures.
2. Market Shares are **persistent**.
3. Technological learning is **firm-specific and local** (it takes place in a neighborhood of technology already mastered). Big jumps are **rare**.
4. Innovation takes time to diffuse. Most innovations are industry specific.
5. Productivity dispersion among firms is high and inter-firm differential are persistent.

Thinking Agents

Agents can be: individuals, economic/social groups, organizations such as firms, banks etc., institutions, physical and biological institutions,...
According to their type they are gathered in different *classes*.

Agents can be composed of other agents, thus permitting hierarchical construction (e.g. a firm composed of workers and managers).

Each agent is thought as a separated, clearly distinguishable entity composed of **data** and **methods**. Methods are procedures that operate on agents' data enabling him to take decisions/actions.

Hence,**agents interact through their methods on the base of their available data**.

The modeler specifies the initial state of the simulated system by specifying the data/behavioral methods of each agent and their degree of accessibility.

Time and Events schedule

At its bottom line, **an AB model can be conceived as a flow of sequential instructions executed by the computer**.
The sequential nature of AB models rises **the important issue of defining the timing of the simulation**, i.e. the sequence of events/actions, or technically speaking, the **order in which agents' methods/functions are called during each period of the simulation** to allow them to interact, take decisions, perform actions.
ABMs in economics allow to consider **asynchronous decisions, different computing times, different processes length** (e.g. different production length).

Outline

Analyzing Results

Ideally, the analysis of results is carried out in two steps:

1. First, the dynamics of the model over simulated time is analyzed to investigate the interactions and causal links that generate the emergent dynamics of the model.
2. Then, synthetic statistics of simulation results are computed, correlations between interesting variables calculated, the distributions of some relevant variable are investigated (e.g. firms' rate growth/size distribution, rates of bankruptcies etc.) and compared to **stylized facts**.

When the model include stochastic elements, there is the need to re-execute the simulations several times in order to generate a reliable distribution of simulation results.

Validation [Fagiolo et al., 2007]

A model approximates 'real world data generating process' *rwDGP* by means of 'model data generating process' *mDGP*.
The extent to which *mDGP* represents a good approximation of *rwDGP* is evaluated through empirical validation (see *Computational Economics* Special Issue on ABMs validation, No.30-3, October 2007).

Validation is composed of two blocks

1. Check **robustness** of results:
   - Sensitivity analysis over micro/macro parameters and initial conditions;
   - Check across-runs variability induced by stochastic elements inside the *mDGP* through *Monte-Carlo simulations*.
2. Proper empirical validation against real world data:
   - Input validation (i.e. how we calibrate the model);
   - Descriptive validation (matching simulated *vs* rw data);
   - Predictive validation (check the ability of the model to produce reliable forecasts over the future dynamics of a system).

Problems affecting AB validation

- Non-linearities and randomness in individual behaviors and interaction networks;
- Micro and macro variables that are governed by complicated stochastic processes cannot be analyzed analytically (here's the need for computer simulation);
- Feed-backs between micro and macro.

These aspects make it difficult to to interpret the outputs of an AB model in terms of its assumptions as the causal links become flaw.
In other words, with the same assumptions, parametrization and initial conditions we can have radically different dynamics.

A simple procedure to accomplish sensitivity analysis

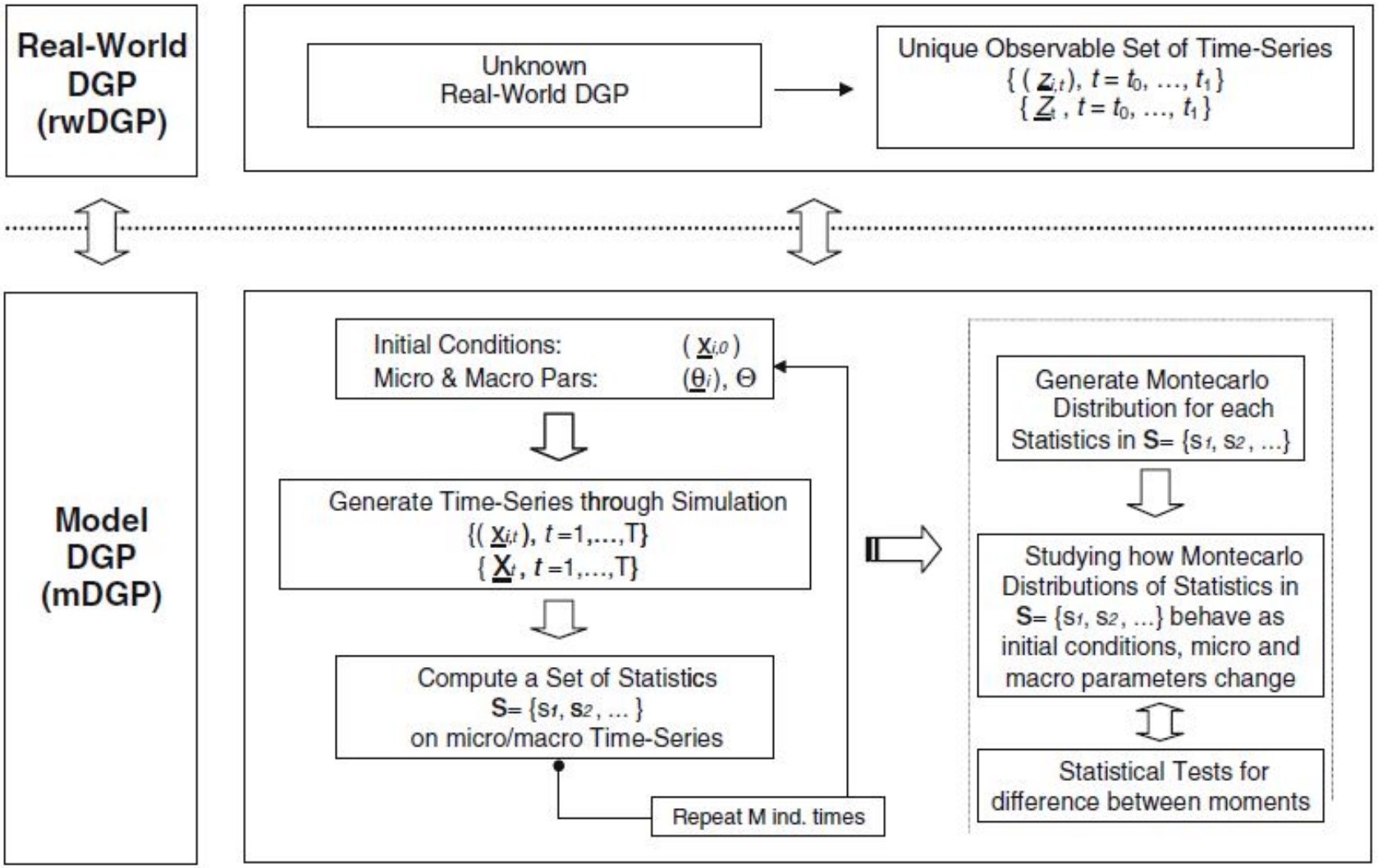

Figure: Sensitivity analysis through Monte-Carlo techniques

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