Evolutionary Processes in Economics:
Multi-agent Model of Macrogenerations Dynamics

Kateryna KONONOVA[1], Maite LOPEZ-SANCHEZ[2]
[1]Karazin Kharkiv National University (Ukraine), kateryna.kononova@gmail.com
[2]University of Barcelona (Spain), maite_lopez@ub.edu

The aim of study

is to model the economic growth of a country as an evolutionary process.

The term '**macrogeneration**' (MG) describes a macroeconomic system that is based on a specific technology and produces a part of gross domestic product (GDP).

Modeling assumptions

1. The economy macro-level can be represented as a set of macrogenerations: each MG produces a part of the GDP and the totality of simultaneously living MGs produces the whole GDP.
2. Each MG is described by an embryonic phase and three phases of growth, saturation and decline.
3. A new MG is born when the current one reaches its limit.
4. The redistribution of resources between macrogenerations corresponds to the phases of their development.

MG identification on the empirical data

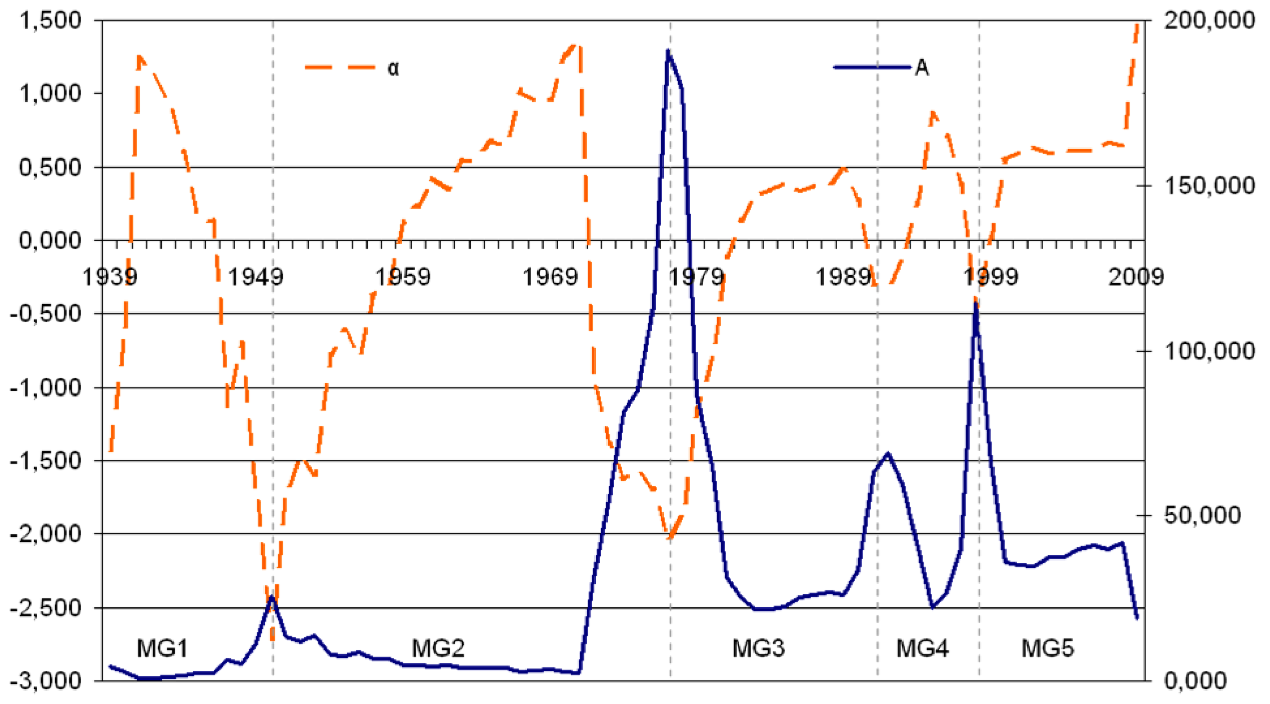
Identification of technological intervals

Parameters drift (*A* and *α*) of the **Cobb–Douglas Production Function** (CDPF) have been analyzed based on US statistics (Gross Domestic Product, Labor Force and Fixed Assets data) within the period of 1930-2011:

$Y = AK^{\alpha}L^{1-\alpha}$, where

Y - GDP,
L - labor input,
K - capital input,
A - productivity factor,
α - elasticity of capital.

Empirically estimated *α* and *A* drift



Drift analysis shows

- the dynamics of these CDPF parameters is **cyclical**;
- α and A vary in **antiphase**;
- in some intervals α becomes **negative**.

To explain the results in terms of evolutionary theory, we have made the assumption that at those intervals where α becomes negative, there is a change of MG when the relationship between the capital and labor changes radically.

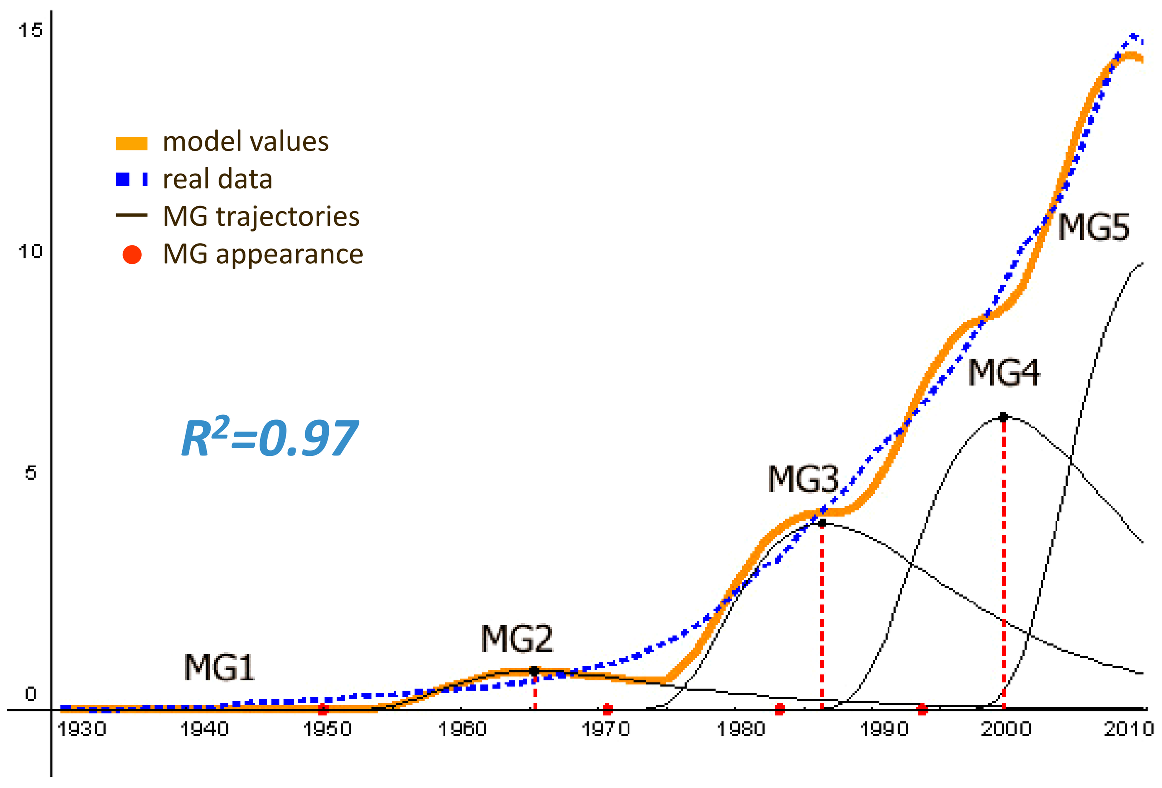
Identification of MG

To describe the macrogeneration life cycle we selected the **log-normal function**.
The criterion was the minimization of squared deviations sum of model values from the real data:

$$z(\tau, M, \mu, \sigma) = \min\left\{\sum_{t=1}^{80}\left(\sum_{i=1}^{5}\frac{M_i}{t-\tau_i}e^{\frac{-[\ln(t-\tau_i)-\mu_i]^2}{2\sigma_i^2}} - y_t^*\right)^2\right\}$$

τ - embryonic phase,
μ, *σ* - technological parameters,
M - potential of macrogeneration,
*y** - US GDP for 80 years.

Approximation of GDP (bil.$) by set of MGs



Analysis of the results

- MGs appear in the **maximum** of their predecessors' neighborhood and have all MG phases
- Intervals between appearance and duration of MGs are **reduced**, τ = {1926; 1950; 1970; 1983; 1993}
- Potential of MGs grow up, M={0.60; 1.00; 4.90; 7.84; 12.34}
- MG **growth phase** corresponds to an **increase** of α
- MG **saturation phase** to an α **local maximum**
- MG **appearance** of new MG to an α **decrease**
- MG **transition** from one MG to the next to a local **minimum** of α

Evolution of MGs: Multi-Agent Based Simulation

Assumptions of multi-agent model

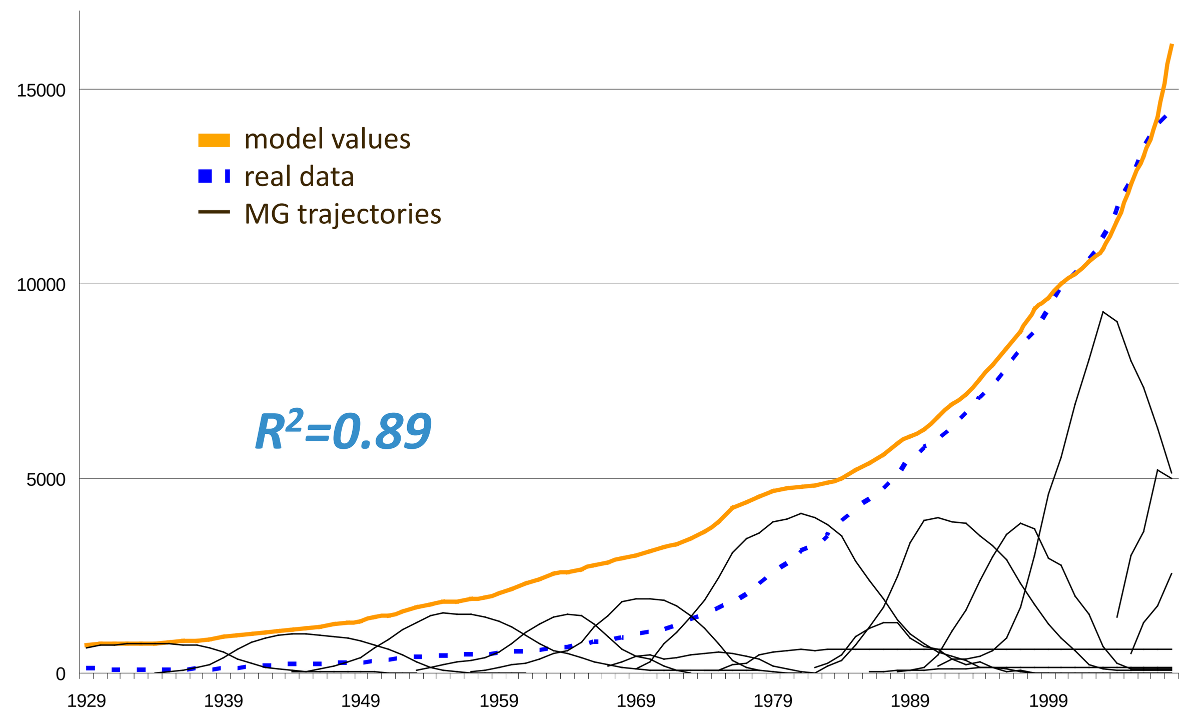
1. A world consists of agents, which can birth and dead depending on their efficiency (an agent dies if its capital K < Kmin and it produces an offspring if K > Kmax). Agents follow CDPF.

2. The technological development could be represented as a result of productivity factor (A) variation. As technological changes come from the entrepreneurs, which have the resources to invest R&D, only 1% of agents with K > 0.5*Kmax are entrepreneurs.

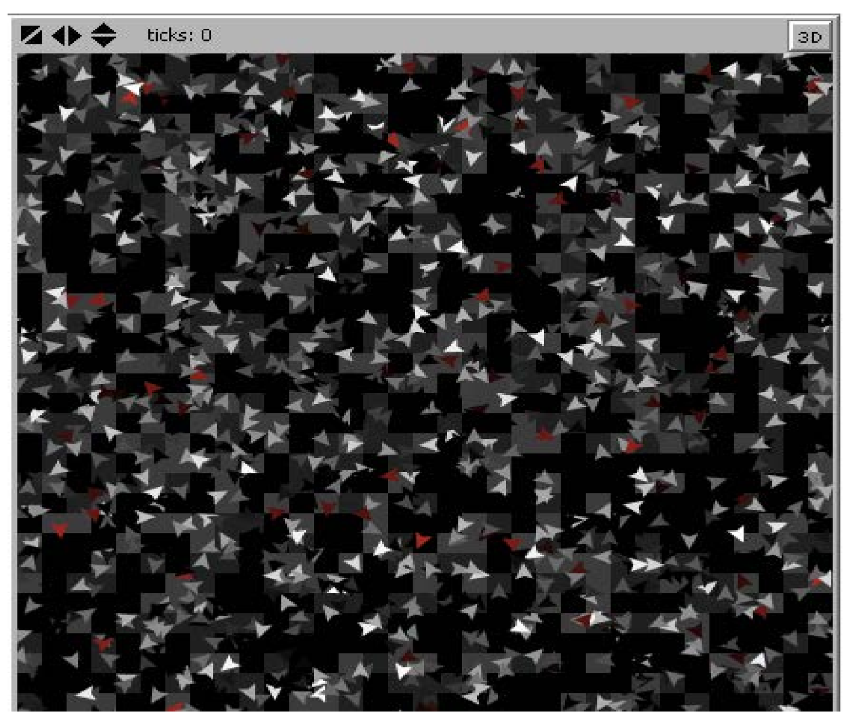
3. Agents know their (8) neighbors' technologies. Each agent has a chance to buy the technology of one of them. The bigger neighbor's productivity factor the higher probability of purchasing from him. The cost of technology is proportional to the technological gap. The neighbor with higher A increases its K because the agent under consideration pays (reduces its K).

4. Transition from one technology to the next corresponds to a local minimum of α, and its growth phase corresponds to an increase of α. Therefore with a new value of productivity factor (A) α falls to a minimum (a0) and then increases (a1) with each simulation step.

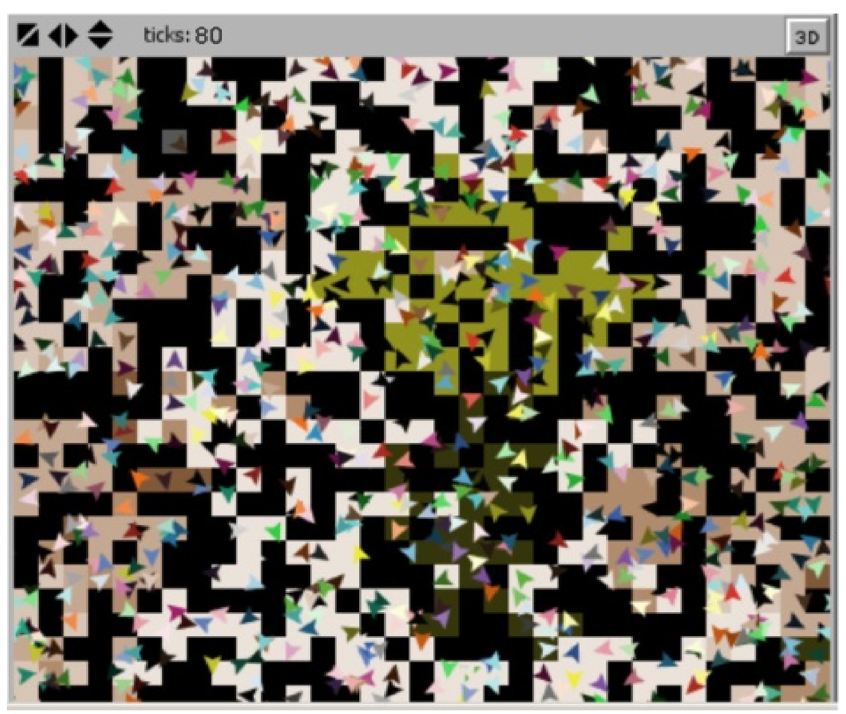
The dynamics of GDP (mil.$) as a set of MGs



Visualization of the model world in NetLogo



At the beginning of simulation most of agents have similar technology and their domains are colored the one color – grey.



Green colored cells in the agents' background show the process of new MG appearance at the epicenter of the previous MG.

Conclusion

- The multi-agent model of MGs evolution which is developed in NetLogo shows the macro-effects, which are not inherent to the individual agent behavior.
- Several waves of mutation and dissemination of a new MGs have been observed during the simulation.
- The observed number of MGs is bigger than it was assumed, some of them are rather small, and some of them are very close to each other.
- **The series of calculations have confirmed theoretical assumptions about the dynamics of the MGs.**